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CONTENTS

Achievements and Possibilities in Pest Eradication.....CLAY LYLE 1
Presidential Address, Fifty-Eighth Annual Meeting, American Association of Economic Entomologists

Effect of Artificial Control Practices on the Parasites and Predators of the Codling Moth.....H. A. JAYNES AND P. E. MARUCCI 9

Saratoga Spittlebug Injury to Pine.....ROGER F. ANDERSON 26

Hosts and Distribution of *Anastrepha serpentina* in Northeastern Mexico.....J. G. SHAW 34

Use of Sulfa Drugs in Treatment of American Foulbrood Disease of Honeybees.....J. E. ECKERT 41

The Sulfathiazole Cure of American Foulbrood: an Explanatory Theory.....J. F. REINHARDT 45

Experiments with Insecticides on Honeybees.....PAUL M. EIDE 49

Controlled Crystallization of Honey.....EDWIN J. ANDERSON 55

The Cabbage Maggot in Northwest Washington.....ELMER C. CARLSON, E. P. BREAKEY AND R. L. WEBSTER 57

The Mode of Absorption of Carbon Tetrachloride by Wheat.....J. H. PEPPER, ELLSWORTH HASTINGS AND T. A. DOUGLAS 64

Toxicity of Some Chlorinated Phenol Derivatives.....CARL J. WEINMAN AND GEORGE C. DECKER 74

A Chlorinated Bicyclic Terpene Used to Control Certain Fruit and Vegetable Insects.....L. A. STEARNS, W. LEROY PARKER, DONALD MACCREARY AND W. A. CONNELL 79

An Analysis of Certain Factors Relating to Control of Grasshoppers with Some Chlorinated Hydrocarbon Insecticides.....CARL J. WEINMAN AND GEORGE C. DECKER 84

Insecticidal Sprays and Dusts for Control of Grasshoppers.....CARL J. WEINMAN, G. C. DECKER AND J. H. BIGGER 91

Toxicity of Certain Esters of Phosphorus Acids to Aphids.....GEORGE F. LUDVIK AND GEORGE C. DECKER 97

A Comparison of Rotenone, DDT, and Benzene Hexachloride for Pea Aphid Control.....H. F. WILSON, W. B. HULL AND A. S. SRIVASTAVA 101

Further Tests for Control of Mexican Bean Beetle and Corn Earworm on Snap Beans.....LOYD W. BRANNON 103

Some Relationships of Insects to Net Necrosis of the Potato in Colorado.....GEORGE M. LIST 107

Effect of Dusting Schedules on the Yield of Cotton.....J. C. GAINES, W. L. OWEN, JR., AND READ WIPPRECHT 113

Effect of Humidity on the Toxicity of Certain Organic Compounds to Eggs of the Body Louse.....GAINES W. EDDY 116

Residual Spray Applications to Salt-Marsh and Jungle Vegetation for Control of Mosquitoes ..... A. H. Madden, H. O. Schroeder and A. W. Lindquist 119

The Permanence of Termite Repellents ..... George N. Wolcott 124

International Air Commerce and Plant Quarantine ..... C. E. Cooley 129

Scientific Notes:

Results with Benzene Hexachloride ..... W. C. O'Kane 133

Dipping in Benzene Hexachloride to Control *Amblyomma americanum* ..... Roland W. Portman 134

Experiments in 1946 on the Control of Bugs that Cause Deformed Peaches ..... Oliver I. Snapp 135

Control of Stored Food Insects with Benzene Hexachloride ..... Stanley J. Carpenter 136

Hexachlorocyclohexane Dusts and Fogs to Control Grasshoppers ..... Roscoe E. Hill and Ephriam Hixson 137

Dusts and Sprays for Grasshopper Control ..... G. M. List and J. L. Hoerner 138

Gynandromorphism in Mosquitoes ..... Margaret Warren and Samuel O. Hill. 139

Announcements 139

Editorial: Keeping up with the Literature ..... Theodore L. Bissell 140

Obituaries: Joseph Henry Merrill 141

Clement Samuel Brimley 141

Meetings:

Entomological Society of Pennsylvania 141

Conference of Army Entomologists 142

Western Cooperative Spray Conference 142

Annual Meeting, Cotton States Branch 143

Annual Meeting, North Central States Branch 143

Proceedings of the Fifty-eighth Annual Meeting, American Association of Economic Entomologists 144

Official Roster, American Association of Economic Entomologists 160

Notice to Subscribers

By action of the Association taken at the Annual Meeting in Richmond, Virginia, in December, 1946, the subscription price of the Journal for non-members of the Association was raised to $5.00 per year within the United States and to $5.50 for foreign addresses.

JOURNAL OF ECONOMIC ENTOMOLOGY
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Achievements and Possibilities in Pest Eradication

CLAY LYLE, *State College, Miss.*

Presidential Address Fifty-Eighth Annual Meeting, American Association of Economic Entomologists

The recent progress in the development of new insecticides and insect repellents has not been equalled in all history. The discovery of the insecticidal value of DDT, closely followed by the amazing emergence of benzene hexachloride from a century of obscurity, has so stimulated research in insect physiology and in the chemistry and toxicology of insecticides as to make certain the synthesis of compounds even more remarkable than these now attracting the attention of the world.

The improvement in methods of application of insecticides merits no less praise. The brief time available does not permit listing all the machines for applying concentrated sprays and dusts by airplane and ground machines. Suffice it to say that at no previous time in history have the achievements of entomologists, working in collaboration with chemists and engineers, been of such universal value as to make in so short a time the name of an insecticide a common word in every household however humble or remote. The entomologist has become a wizard in the eyes of the uninitiated—and indeed some of the achievements seem little short of magic.

Unfailing evidence of this rise of the entomologist in popular favor is shown in increased expenditures for pest control. These increases in most cases are far beyond those justified by rising prices and apparently indicate a willingness to follow the leadership of entomologists in attacking problems which have long needed attention.

With all of this scientific progress and with the world believing in our ability to accomplish great things, should we not consider whether our post-war plans in entomology—local, national and international—are as comprehensive and as challenging as this favorable situation justifies? Is not this an auspicious time for entomologists to launch determined campaigns for the complete extermination of some of the pests which have plagued man through the ages?

Certainly we should be encouraged by the achievements of those who worked without these modern weapons but had no lack of enthusiasm and courage for their tasks. We do not know who first thought of the possibility of eradicating a pest. Undoubtedly many of the early entomologists indulged in wishful thinking but did not have the insecticides or equipment to justify serious consideration of the problem. Even in the voluminous writings of B. D. Walsh and C. V. Riley I find no mention of the possibility of exterminating a pest.

In preparing a chronological record of eradication projects, I have included only those pests which have become well-established and have either been wholly exterminated, or have been eliminated from areas of sufficient size to prove the practicability of eradication in other areas under similar conditions. In gathering this information the assistance of entomologists in the United States and other countries has been very helpful.

ERADICATION RECORDS IN THE UNITED STATES.—*Gypsy Moth.*—Apparently the first official extermination campaign began in Massachusetts in 1890 with the appropriation of $50,000 for work against the gypsy moth, *Porthetria dispar* (L.). Unfortunately this program was abandoned by the Massachusetts Legislature in 1900 because such good results were secured there was no longer any popular interest in control. Later the gypsy moth

was eradicated from an area in Pennsylvania by 1923. After 10 years' effort and the expenditure of about $2,000,000 it was exterminated from more than 400 square miles in New Jersey by 1930. It will be mentioned again in this paper.

Cattle Tick.—Almost immediately after the epoch-making discovery of Smith and Kilbourne, the possibility of eradicating the cattle tick, *Boophilus annulatus* Say, received consideration. Apparently the first recorded statement is that of Dr. Cooper Curtice, who in 1896 said:[1]

> "I look most eagerly for the cleansing of even a certain portion of the infested territory under the direct intention of man, for it opens the way to pushing the ticks back to the Spanish isles and Mexico, and liberating cattle from disease and pests and the farmer from untold money losses. Let your war cry be: Death to the ticks."

This work began in North Carolina in 1899 with rather discouraging progress at first, for 7 years later only 12 counties had been released from quarantine. Only within the past two or three years has the continental United States become practically free from this pest. The long story of discouraging political setbacks, the dynamiting of vats and the killing of inspectors emphasizes the need for an outstanding educational program in advance of any compulsory undertaking of this kind.

Date Palm Scale.—In 1907 the Territory of Arizona authorized its agricultural experiment station to begin an eradication program on the date palm scale, *Parlatoria blanchardi* Targ., which had become established at several points in Arizona and California and was later found in Texas. By 1910 it was reported a rare insect in Arizona and the original infestation at the experiment station was eradicated by 1914. Work against the Texas infestation began in 1915 and eradication was completed in 1919. However, the other infestations in Arizona and California continued for many years longer and not until 1936 was eradication finally announced.

San Jose Scale.—In 1907 the Kansas State Entomological Commission was created by the legislature "to suppress and eradicate San Jose Scale and other dangerous insect pests and plant diseases." Since that time this scale has been apparently eradicated from 11 counties in the northern and northwestern parts of the state. Some of the infestations were large and several years were required to achieve eradication.

San Jose scale was discovered at Mitchell, South Dakota, in 1915 and eradicated by 1918.

A large infestation of San Jose scale was found in Minnesota in 1934 and was eradicated after 3 years of continuous spraying and cutting out infested stock.

Pink Bollworm.—In 1917 the pink bollworm, *Pectinophora gossypiella* Saunders, was found for the first time in the United States at Hearne, Texas. Two other infestations in Texas were discovered the same year, one of them comprising more than 6000 acres. Eradication by means of non-cotton zones was completed in 1918. Dr. C. L. Marlatt, Chairman of the Federal Horticultural Board at that time, referred to this achievement as "the largest successful entomological experiment in history." The pink bollworm has since been eradicated from larger areas in several states, notwithstanding its very threatening position at present.

Banana Root Borer.—Infestations of the banana root borer, *Cosmopolites sordidus* (Germ.), were discovered in Florida in December, 1917, and later investigations revealed about 25 properties infested in three counties. Eradication by destroying the infested plants was completed by the end of 1920.

Sweetpotato Weevil.—In 1918 an eradication program against the sweetpotato weevil, *Cylas formicarius elegantulus* (Sum.), was started on 217 farms in Baker County, Florida and Charlton County, Georgia. The work was completed by 1924. The sweetpotato weevil has since been eradicated from thousands of farms in several southern states. Eradication methods have been standardized and there seems no reason why this pest should not be ultimately exterminated from all farming areas.

White Snail.—In 1918 the eradication of the white snail, *Helix pisana* Muller, was started in several southern California counties and is now being successfully concluded at a cost of about $235,000.

Argentine Ant.—The first successful effort at eradicating the Argentine ant, *Iridomyrmex humilis* Mayr., was at Fayette, Mississippi, beginning in 1922. The

[1] *Jour. Comp. Med. & Vet. Arch.* Vol. 17, p. 655, 1896.

town was declared free of the ants in 1924. More than 30 other infestations of this ant have since been eradicated in Mississippi.

Citrus White Fly.—In 1928 eradication measures were started against the citrus whitefly, *Dialeurodes citri* (Ashm.), in 16 infested counties in California. The project was announced completed in 1942 at a cost of about $385,000.

Mediterranean Fruit Fly.—In April, 1929, the Mediterranean fruit fly, *Ceratitis capitata* (Weid.), was discovered in Florida in portions of 20 counties, involving a quarantined area of more than 8,000,000 acres. The eradication of this infestation in slightly more than one year is an everlasting tribute to Dr. Wilmon Newell and the state and federal workers associated with him.

Citrus Blackfly.—The citrus blackfly, *Aleurocanthus woglumi* Ashby, was found in Key West, Florida, in 1934 and eradicated in 1937 at a total cost of approximately $200,000.

Obscure Scale.—Eradication of obscure scale, *Chrysomphalus obscurus* (Comst.), from Los Angeles and San Diego Counties, California, where a considerable amount of nursery stock and some very large pecan trees were infested, began in 1934 and was announced completed in 1944, no specimens having been found for 3 years.

ADDITIONAL RECORDS.—There are numerous instances of local eradication of pests which might not have been present long enough to become well-established, or in which the extent of the infestation was not sufficient to draw conclusions as to the practicability of eradication on a large scale. For example, Harold J. Ryan reports the eradication of 25 species from Los Angeles County, California.[1] He states:

> "Of these, 18 were scale insects and one a mealybug, all incapable of natural rapid spread as compared with insects having winged adult forms. Twelve of these were certainly or probably established but a short time before they were found. Of the six non-Homoptera, five species were of recent establishment."

His report is convincing evidence of the value of maintaining constant vigilance for new pests.

Among other records of local eradications, the Japanese beetle has been exterminated at Louisville, Kentucky, Charleston, South Carolina and several other places where incipient infestations were discovered early and treated promptly.

The Mexican bean beetle, *Epilachna varivestis* Muls., was found in Minnesota in 1933 and eradicated the same year.

The sugarcane mealybug, *Pseudococcus boninensis* (Kuw.) was introduced into Mississippi in 1927, discovered on several farms in 1929, and eradicated by 1932. A later introduction in another part of the state was also eradicated promptly.

The legume weevil, *Hypera brunneipennis* (Boh.), was discovered at Yuma, Arizona in 1938 and eradicated from a 10-acre field. Later it was found to be of no economic importance and efforts at eradication in other areas were discontinued.

Several infestations of the fowl tick, *Argas persicus* (Oken), have been discovered in Mississippi and promptly eradicated. It is possible that it would not have survived anyhow since it has had ample opportunity to become established in the Gulf States but apparently has not done so.

The potato tuberworm, *Gnorimoschema operculella* (Zell.), was found in Minnesota in 1940 and was reported eradicated by 1943.

Three small infestations of white-fringed beetles (*Pantomorus* spp.) have been eradicated in Mississippi, Louisiana and Alabama but large scale efforts have not been successful.

A small infestation of the sweetpotato weevil was found at Hutchinson, Kansas, in 1941 and promptly destroyed.

An orchid weevil, *Cholus cattleyarum* Barber, was found in a Milwaukee greenhouse in 1916 and seems to have been eradicated the following year.

Another pest of orchids, the Dendrobium weevil, *Diorymerellus laevimargo* Champ., was reported eradicated from a Maryland greenhouse in 1945 after several applications of DDT. The same treatment also eliminated the thrips *Physothrips xanthius* Williams and scale insects, according to E. N. Cory.

The tomato pinworm, *Keiferia lycopersicella* (Busck), was found in a greenhouse at St. Joseph, Missouri, in 1936 and eradicated by 1938.

The chrysanthemum gall midge, *Diarthronomyia hypogaea* (Loew), has been

[1] Bull. Cal. State Dept. Agr., Vol. 35, No. 3, pp. 124–5, 1946.

eradicated from several Mississippi greenhouses and is not known to occur in the state.

Among eradication projects now in progress, one is directed against the western grape skeletonizer, *Harrisina brillians* B. & M. D., involving an area of about 2500 square miles in San Diego County, California, on which about $100,000 is expended annually. Another is against the Mexican bean beetle which was found in California this summer, its first appearance on the Pacific Coast. Only about 2000 acres are involved at present. About $100,000 has been spent already and equal amounts are planned for the next two years.

In northwestern Kansas two infestations of the European elm scale, *Gossyparia spuria* (Mod.), are receiving concentrated attention with power sprayers and eradication is expected.

The infestation of the sweetpotato weevil in Arizona discovered in October of this year will undoubtedly be eradicated at once.

ERADICATION RECORDS IN OTHER COUNTRIES.—There are several records of the eradication of important pests from other countries, some of the projects involving thousands of square miles.

Colorado Potato Beetle.—Europe has been constantly on the defensive against the Colorado potato beetle, *Leptinotarsa decemlineata* (Say), ever since this pest spread through our eastern states. It is recorded as reaching the Atlantic Coast in 1874 and the first infestation was found in Germany in 1877. It was again found in Germany in 1887, in 1914 and in 1934. In each instance it was promptly eradicated.

The Colorado potato beetle was found in England in 1901 and again at almost the same place in 1933. It has been found several times since 1933 but was quickly eradicated each time, according to Dr. W. J. Hall, Director of the Imperial Institute of Entomology.

In 1922 the Colorado potato beetle was found in France over an area of about 100 square miles. Eradication efforts were not successful and it has since spread over a large part of Europe, including Belgium, Holland, Germany and Switzerland, and will no doubt be reported in increasing numbers in England as the whole continent becomes infested.

Brown-Tail Moth.—In 1902 the brown-tail moth, *Nygmia phaeorrhoea* (Donov.), was found in Nova Scotia. Bounties were offered for the collection of larval "nests" for several years and organized scouting and destruction of the nests began in 1907 in both Nova Scotia and New Brunswick. Eradication was apparently completed in New Brunswick in 1918 and in Nova Scotia in 1928. A recent reinfestation in New Brunswick seems to have been eradicated.

Gypsy Moth.—The gypsy moth was found in southern Quebec in 1924 and was apparently eradicated by 1927. An infestation was found in New Brunswick in 1937 and was stamped out by 1941, according to H. G. Crawford, Dominion Entomologist of Canada.

Codling Moth.—Between 1903 and 1928 there were 11 infestations of the codling moth, *Carpocapsa pomonella* (L.), in western Australia—6 of them in orchard districts. All were eradicated although some of the infestations required two seasons' work. All fruit was destroyed and the trees cut back so no fruit would be produced the following year. In no case did the moth reappear within 50 miles.

Cattle Grubs.—Both species of cattle grubs, *Hypoderma bovis* (DeG.) and *H. lineatum* (DeVil.), have been eradicated from Clare Island, Ireland. The work began in 1915 and was completed in 1920.

Mosquito Eradication.—An outstanding instance of mosquito eradication is the elimination of *Anopheles gambiae* Giles from Brazil. This species was found in Brazil in 1930 and serious outbreaks of malaria occurred in a small area that year and in 1931. It did not attract attention again until 1938 when it caused the deaths of about 20,000 persons in the 12,000 square miles it then occupied The Brazilian Ministry of Health, cooperating with the The Rockefeller Foundation, concluded a successful eradication program by the end of 1940.

Apparently a very successful campaign is also being waged in Brazil for the complete eradication of the yellow-fever mosquito, *Aëdes aegypti* (L.). A very intensive program has been under way for several years and many large areas now seem to be free of this species.

In 1943 *Anopheles gambiae* was reported to have caused more than 130,000 deaths in Egypt, having extended its area from

the Sudan along the Nile to within 200 miles of Cairo. The Egyptian Government, cooperating with The Rockefeller Foundation assigned more than 4000 personnel to the task of eradicating this species, which was reported accomplished by the end of 1945.

Tsetse Flies.—In southern Rhodesia *Glossina morsitans* Westw. has been eradicated from more than 6000 square miles during the past 10 years, following a program based on the destruction of all big game in fenced belts 10 miles in depth and 100 or more miles wide.

A different method has been successful on the Gold Coast in West Africa against *Glossina palpalis* R.-D., and *G. tachinoides* Westw. From 1940 to 1945 more than 1000 square miles in an area of very heavy incidence of sleeping sickness were freed of these flies by clearing stream banks of certain vegetation.

In Zululand in the Union of South Africa, where *Glossina pallidipes* Aust. is the predominant species, a large-scale experiment in eradication is now being conducted on 40 square miles of bush country, applying a DDT solution by airplane. A recent letter from Dr. Rene du Toit, Veterinary Officer, gives some very interesting details. As to results, he says:

"In the Mkuzi Reserve 5 applications spaced at two-weekly intervals have to date resulted in the almost entire elimination of the tsetse flies in the area. . . . So far as other species of insects are concerned the effect upon *Anopheles gambiae* has been profound. This is a notorious malaria area and not a single case of malaria has developed in a personnel of approximately 50 camped in the area throughout the summer months."

Thus it would seem that in any area in which tsetse flies are eradicated by chemical means malaria might also disappear.

INSECTS WHICH SHOULD BE ERADICATED.—In considering the insects which should be eradicated in the near future, I am omitting, with one exception, those which are already subjects of federal eradication or control projects. The exception is the gypsy moth and I mention it only because of the greatly improved possibilities for eradication through the use of airplanes rapidly and inexpensively covering large areas with small amounts of DDT instead of the slow, costly and laborious application of lead arsenate spray used until the past year or two. Practically perfect control is being secured. R. A. Sheals, in charge of this federal project, writes:

"Certainly very significant progress has been made in gypsy moth control since the advent of DDT and the development of new and more effective types of distributing apparatus. During the year ending June 30, 1946, this Division and its cooperators treated in excess of 127 square miles of gypsy moth infested woodlands. This is more acreage than has been treated for gypsy moth control in any previous 6 fiscal years. Treatment by aircraft, including all expenditures incident to that type of work, plus 10 per cent for overhead, cost $1.45 per acre. This may be compared with the cost of treating areas in previous years with arsenate of lead dispensed from high-powered ground spray equipment at a cost ranging from 15 to 25 dollars per acre. The effectiveness of DDT compared with arsenate of lead or other chemicals used is amazing. No persisting infestation has been found on any area treated by aircraft during 1944 and 1945."

Certainly there seems to be every reason for optimism about the success of this project in the not too distant future.

The House Fly and the Horn Fly.—The time has now arrived for the eradication of the house fly, *Musca domestica* L., and with it the horn fly, *Siphona irritans* (L.). These two should be considered together for in all rural and suburban areas the eradication measures would be used against both at the same time. The eradication of the house fly and the horn fly from the United States today would be a far simpler task than the eradication of the Mediterranean fruit fly from Florida in 1929. The program should be voluntary at first, with as much publicity as possible about the results secured and the feasibility of complete eradication. Public sentiment would then support any compulsory measures necessary for completing eradication. Already results in several sections of the country for the first year after the release of DDT for civilian use give promise of what may be expected when more sprayers become available and the spraying of livestock and barns is a general practice. Ray Cuff of the National Livestock Loss Prevention Board reports that half the cattle in Oklahoma and Kansas were sprayed this summer and quotes a Kansan as saying: "This is the first summer when we did not actually need screen doors." At State College, Mississippi, where cattle and barns were sprayed for horn flies and house flies, and garages, basements and various other locations were sprayed for mosquitoes, the scarcity of house flies was noticed by everyone, in

spite of the most favorable fly-breeding summer in years. Some dairymen in Mississippi reported no flies in their barns for as long as six weeks at a time. In Oklahoma, the State Board of Agriculture secured 190 large army decontamination sprayers on trucks and sent them practically all over the state. In Arkansas, New York and many other states commercial spraying of barns and cattle occurred on a large scale and received much publicity. Last spring Idaho, through the leadership of W. E. Shull and H. C. Manis, was apparently the first state to promote a fly eradication campaign. A very effective poster carrying the slogan "No Flies in Idaho" was scheduled for display in 10,000 public places. Dr. Manis writes:

> "During August and September when our fly populations are normally at their peaks, it was almost impossible to find a fly anywhere. Many town residents left their screens off during the entire summer and it was not unusual to notice in the downtown district restaurants and cafes with their screen doors wide open. Yet an examination inside showed no flies present.
>
> "One incident will point out this fact more clearly. One of our major students in entomology, wishing to commence a laboratory problem on some research work on DDT, decided to use house flies as the test insect. He set up two fly traps in the city of Moscow —one beside a slaughter house and another across town by some garbage cans—and during a two-week period was unable to trap a single house fly. He finally located 12 flies in a farm house and from those was able to start a laboratory culture. This could probably have occurred in any town in Idaho and on almost any farm. The results on a state-wide basis were so outstanding that it was almost beyond belief."

Although results elsewhere may not have been so spectacular as in Idaho, flies have been greatly reduced in many areas this fall. If the campaigns are pushed vigorously early next spring there should be many situations before the end of 1947 where a city or county health officer will be asking anybody who has seen a fly to report it, after which a spraying crew will visit the property to locate and destroy breeding sources. This is not a fantastic dream but is something that is almost certain to happen, and we as entomologists should be the driving force of the movement, enlisting the aid of health and veterinary departments, farm organizations, livestock associations, civic clubs and other agencies. If entomologists do not take the leadership in this program somebody else will.

Cattle Grubs.—High on the list of insects which should be eradicated are the two species of cattle grubs. A few years ago it was estimated that these pests cause an annual loss in the United States of more than $100,000,000, with some estimates as high as $300,000,000.

As early as 1896 we find an entomologist stating that cattle grubs could be practically exterminated in a single year. When we consider that the most effective method in use at that time consisted in squeezing them out we must pay tribute to the optimistic enthusiasm of the author who was none other than Professor Herbert Osborn. The eradication of both species from Clare Island, Ireland, was achieved by this slow, painful method. The present convenient, painless and inexpensive methods of applying insecticides in dust or spray form, together with the excellent results secured, have made cattle grub control very popular with farmers. After observing the farmer reaction while conducting more than 50 cattle grub control demonstrations during the past three years, I am convinced that, preceded by a high degree of voluntary control and the right kind of educational campaign, there would be little difficulty in voting compulsory cattle grub eradication in many states. Present methods, although very effective, would be greatly supplemented by the development of an adhesive toxicant which could be applied to the animals during the oviposition period of the flies. Even without this, cattle grub eradication programs might well be inaugurated in nearly every state with splendid opportunities for success.

Cattle Lice.—The eradication of cattle lice would logically accompany a cattle grub eradication program and the double objective would have more appeal for farmers, legislators and county boards of supervisors. The success of the present inexpensive methods is so outstanding that there is no question of the practicability of eradication. Cattle lice were almost unknown in parts of the South during the tick eradication program and it is probable that the present widespread use of DDT for horn fly control will greatly aid in eliminating lice also.

A comprehensive health and livestock pest eradication program including the extermination of the house fly, the horn fly, cattle grubs and cattle lice would

have a very powerful appeal in any farm state.

Screwworm.—The screwworm, *Callitroga americana* (C. & P.), does not overwinter north of Florida and the extreme southern part of Texas. From these areas it spreads north each season. Eradication from Florida during the winter would free all the southeastern states from attacks. Eradication seems quite possible technically, but will require the destruction of wild hogs and probably some other wild animals, in addition to the cooperation of all livestock owners. Cooperative work with Mexico may also make it possible to prevent the northward spread through Texas each year. It is a problem which challenges the best cooperative efforts of entomologists and livestock owners.

Argentine Ant.—This important pest has become widely established in the southern states and in California during the past 50 years. Although the present infestations probably comprise much less than 0.1 per cent of the whole area of the infested states, its continued spread and eventual overrunning of all the South is almost certain unless control or eradication measures are begun. In towns and thickly-settled rural areas eradication is very practical and can be financed with local funds, as has been demonstrated at several dozen separate localities in Mississippi. Where large infestations occur in thinly-settled rural sections, the technical problem of eradication is no greater, but local funds must be supplemented from other sources. The eradication of the Argentine ant would pave the way for the eradication of the sugarcane mealybug and perhaps other species flourishing in a symbiotic relationship with it.

Other Species.—There are several other species which should be comparatively easy to eradicate, mainly animal parasites, including horse bots, sheep and goat lice, the hog louse and the so-called sheep tick.

In some other cases the task would not be too difficult, but the need for it is hardly great enough to justify a nation-wide campaign. For example, some localities would be warranted in making large expenditures to eliminate *Anopheles quadrimaculatus* Say, but the cost of eradicating it from the United States would be out of proportion to the danger involved, even with malaria-infected veterans in all sections of the country. A letter just received from Dr. Fred L. Soper in Egypt, who conducted the successful campaigns against *Anopheles gambiae* in that country and in Brazil, indicates his concurrence in the opinion that the eradication of *A. quadrimaculatus* from the United States is unnecessary.

Human lice would also come in this classification. Eradication would be simple but a nation-wide compulsory physical examination would be necessary to find the infested few. Only the imminence of another war, in which a large segment of our population would be crowded underground, would justify this extreme measure.

The bedbug, *Cimex lectularius* L., is another example of this group. With no disease threat involved, and only a very small percentage of our population concerned at any time, a compulsory campaign would not be justified and a voluntary one would fail from lack of interest. If hotels and lodging places are indifferent about bedbugs, local ordinances would seem to be the remedy.

Some pests have not been mentioned on account of the present lack of sufficient quantities of the effective insecticide. For example, the harlequin bug, *Murgantia histrionica* (Hubn.), the squash bug, *Anasa tristis* (DeG.), and probably some other bugs with a limited number of host plants could be easily exterminated if enough sabadilla were available. A synthetic substitute, which could be produced in large quantities, would solve this problem.

Again, I have not included widely-distributed pests which could be eradicated by eliminating the hosts, because of the difficulty of providing a satisfactory governmental basis for enforcing eradication. For example, the boll weevil, *Anthonomus grandis* Boh., could be eradicated within 5 years without much disruption of total production by means of a succession of non-cotton zones gradually extending across the cotton states, but no state would voluntarily adopt the legislation necessary to start such a program. There are probably several other pests, the eradication of which would be technically quite feasible but politically impossible.

I have excluded from present consideration most field, orchard, garden and forest pests, largely because our knowledge of

the insecticides effective against some of them is not yet sufficient to make certain that we would not greatly disturb the "balance of nature" by large-scale field applications. This paragraph from a recent letter indicates that it is not difficult to create a faunal desert in some cases:

"Following 5 per cent gamma in talc, applied by airplane at rates of 10 to 12 pounds per acre, the following were taken from the ground dead or paralyzed: aphids, beetles of several species, bollworm moths, bollworm larvae, leafworm moths, leafworm larvae, spiders, bees, *Geocoris*, aphis lions, flies of several species, tiger beetles, rapid plant bugs, tarnished plant bugs, *Neurocolpus*, velvetbean caterpillar moths, 12-spotted cucumber beetles, grasshoppers, boll weevil parasites, ladybird beetles, leafhoppers and ants. In a field treated with 12 pounds per acre of the same material, applied 6 times by airplane, no insects were ever seen, although there were a few red spiders on practically every leaf."[1]

Most of our economic plants are so dependent on insect assistance in pollination we cannot safely plan wide-scale distribution of such deadly materials until we know more about their effects on beneficial species.

In conclusion, may I plead for your serious consideration of the proposals for the eradication of these age-old pests. Let us not be satisfied with anything less than a post-war program which will challenge the imagination of the world. All of us, whether engaged in teaching, research, extension, regulatory or commercial phases of entomology, will have many opportunities to keep the public informed of what can be accomplished.

We have the technical knowledge and equipment to eradicate the house fly, horn fly, cattle grubs, cattle lice and several other insects, but in each case we must secure a high degree of control through voluntary participation before public sentiment will compel final eradication by law. Unless we can enlist the aid of farmers' organizations, public health agencies, schools, chambers of commerce, the press, civic clubs, city and county officials, legislators and members of Congress, we shall not succeed. May I urge that you again read the article in *The American Scientist* for January, 1946, entitled "Scientists Should Knock at the Door of Politics" by M. L. Cooke. We must develop political know-how to secure funds and cooperation in executing our plans. Furthermore, we must actively seek international cooperation. Some of our worst pests cannot be eradicated without the assistance of our neighbors. The World Health Organization of the United Nations may be very helpful in focusing attention on the danger spots of the world and in bringing our united resources to bear in eliminating them. In all these activities entomologists should be in the very front line, the active agents and synergists of the movement. More than once during the past year I have heard the complaint that entomologists are not being accorded the recognition rightfully due them. Could it be possible that part of the fault may lie in us? Let us examine our programs carefully. In the words of Daniel Hudson Burnham, let us

"Make no little plans. They have no magic to stir men's blood."—12-11-46.

[1] Letter from E. W. Dunnam, Leland, Mississippi.

PACIFIC SLOPE BRANCH TO MEET IN JUNE

The thirty-first annual meeting of the Pacific Slope Branch of the Association will be held in Berkeley, California, on June 23, 24 and 25, 1947. All sessions will be held in the Hotel Claremont, the headquarters for the meetings.

A program of some fifty papers is planned and a large attendance is expected. Papers are to be presented in summary form and published in their complete form.

A more attractive suggestion for a vacation trip for entomologists in the East could scarcely be made and any who may go are assured of a welcome and an ideal mixture of pleasure and professional interest.

Effect of Artificial Control Practices on the Parasites and Predators of the Codling Moth

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Although the codling moth, *Carpocapsa pomonella* (L.), is the major insect pest of apples in this country, very little work has been done on its control by biological measures. In 1936 a biological-mechanical codling moth control project was started by the Bureau of Entomology and Plant Quarantine in cooperation with the West Virginia Agricultural Experiment Station, to determine whether, under conditions prevailing in West Virginia, it was practicable from the commercial point of view to reduce or eliminate the spray schedules but to continue all other control measures. In West Virginia a high degree of control of the codling moth is not usually attained, even when 4 to 7 cover sprays are applied. Fruit infestation is not limited to 5 per cent or less, as it is in some other sections of the country when this number of sprays, or even fewer, are used. In 1938 the work was extended to include a study of the relative value of various natural-control factors and the effect of the artificial-control practices on these enemies of the codling moth, and to develop methods of sampling for parasite, predator, and host populations and of evaluating and comparing natural-control values in sprayed and unsprayed orchards. The results of the Bureau's studies in two orchards in 1938, 1939, and 1940 are reported in this paper.

THE EXPERIMENTAL ORCHARDS.—An 18-acre orchard about 30 years old, located 12 miles west of Kearneysville, was utilized for the biological-control experiment. It contained 574 trees, including 255 York Imperial and 96 Ben Davis (Ganoes), the varieties chosen for this study. The orchard is located on deep, fertile soil, which is well drained for both air and water

In the winter of 1935–36 and each year thereafter the orchard was pruned and thoroughly scraped. On April 6, 1936, sodium nitrate was applied at the rate of 7 pounds per tree. This was the first commercial fertilizer that the orchard had ever received. The same amount of sodium nitrate was applied the next spring. In April 1937 the orchard was thoroughly disked and seeded to yellow and white sweetclover and winter hairy vetch. A 4–12–4 fertilizer was used at the rate of 300 pounds per acre. The orchard was kept in sod with clean cultivation beneath the trees, and weed growth being carefully removed by hand.

The trunks and all main scaffold branches were banded with untreated 2-inch corrugated-cardboard bands. These bands were removed at 7- to 10-day intervals throughout the season and replaced with new bands. Care was taken to remove all larvae on the tree under the bands. The infested bands were placed in a screen cage, centrally located in the orchard, where the moths and parasites were allowed to emerge but only the parasites could escape into the orchard. A few of the larger species of parasites, which were unable to escape through the 12-mesh wire screening, were captured in vials and liberated.

A commercially sprayed orchard located just north of the biological-control orchard and separated from it by 21 rows of apple trees was selected for comparison. This orchard was comparable to the biological-control orchard and contained 148 York Imperial and 196 Ben Davis trees. The commercial orchard was pruned each winter, and some of the roughest bark was scraped. Commercial fertilizer was applied each spring. All bearing trees were banded with chemically treated bands, except the count trees, the trunk and main scaffold branches of which were thoroughly scraped and then banded with 2-inch strips of corrugated cardboard.

Since the end product by which codling moth control is adjudged is the amount of injury to the fruit, it seems advisable to indicate the infestation records of the two

[1] The writers are indebted to C. P. Clausen, in charge of the Division of Foreign Parasite Introduction, for suggestions and criticism during the experiments here reported and in the preparation of the manuscript. They wish to express their gratitude to Edwin Gould, of the West Virginia Agricultural Experiment Station, and E. O. Hamstead, of the Division of Fruit Insect Investigations and J. H. Geissler, formerly of that Division for their full cooperation; also to W. G. Cushwa and W. Gatrell, owners of the orchards used in these experiments. Acknowledgment is due members of the Division of Insect Identification for determination of the parasites and predators.

orchards before discussing the biological-control factors that were in operation. According to unpublished data of Mr. Gould and Mr. Geissler, the commercial orchard had higher percentages of total sound fruit (harvest and drop fruit) in all three years. The percentages of sound fruit in the commercial orchard were 56.0, 69.9, and 75.0, as compared with 37.5, 38.3, and 28.0 in the biological-control orchard for the years 1938, 1939, and 1940, respectively.

In the commercial orchard 72 per cent of the harvested fruit was sound during the three years, and in the biological-control orchard 50 per cent was sound.

In all three years, at the beginning of the second brood, the biological-control orchard had a much higher population of worms than did the commercial orchard. However, despite the fact that the commercial orchard carried on with a typical commercial spray program at the beginning of the second brood, and considering the comparative population, the number of injured fruits while this brood was present was proportionately much higher than in the biological-control orchard.

SPRAY SCHEDULES.—For the five years 1936 to 1940, inclusive, the biological-control orchard was given a dormant or delayed-dormant oil spray, followed by a pink spray of lime-sulfur and a petal-fall spray of lime-sulfur, lime, and lead arsenate. No cover sprays were applied to this orchard.

The sprays applied to the commercial orchard, especially the cover sprays, varied considerably during the three seasons. In 1938 this orchard received a late delayed-dormant oil spray, a pink spray of lime-sulfur, and a petal-fall spray of lime-sulfur, lime, and lead arsenate. The first cover spray consisted of lime-sulfur, lime, and lead arsenate; the second of nicotine, summer oil, lime, and lead arsenate; the third and fourth of commercial nicotine bentonite and summer oil; and a fifth of a commercial nicotine-summer oil preparation.

In 1939 the commercial orchard received a dormant oil spray with tar oil added for aphid control; a pink spray of lime-sulfur; and a petal-fall spray of lime-sulfur, lime, and lead arsenate. The first cover spray consisted of lime-sulfur, lime, and lead arsenate; the second of lime and lead arsenate; the third of lead arsenate, calcium arsenate, lime, and copper sulfate; and the fourth of a commercial summer spray oil containing nicotine.

In 1940 the commercial orchard received a dormant oil spray with tar oil added; a pink spray of lime-sulfur; and a petal-fall spray of lime-sulfur, lime, and lead arsenate. The first cover spray consisted of copper sulfate, lime, and lead arsenate, with nicotine added for three-fourths of the trees; the second of copper sulfate, lime, and lead arsenate; and the third of nicotine, lime, and summer oil.

NATURAL CONTROL.—The natural enemies found attacking the codling moth in the apple orchards of West Virginia consisted of parasitic and predaceous insects and a fungus disease.

EGG PARASITES.—To determine the extent of parasitization by *Trichogramma minutum* (Riley), search was started on May 13, 1938, and continued until June 14, for codling moth eggs on the foliage and fruit in both the biological-control and the commercial orchards. It soon became evident that not enough eggs could be found to give a satisfactory comparison of the parasitization in the two orchards. Methods were then developed to induce the codling moth to deposit eggs on cellophane paper in cages. The cellophane paper bearing freshly laid eggs was cut into small sections containing 1 to 3 eggs each, and the sections were pinned to the leaves on 6 to 12 trees, from 5 to 11 being placed on each, throughout the two orchards. These sections were gathered before the eggs hatched, and records were taken of the number of eggs parasitized and the number of sections on which parasitized eggs were found.

The parasitization recorded for codling moth eggs placed in the two orchards while the first and second broods were present is summarized in table 1. The greatest difference occurred in 1938, when parasitization was considerably higher in the biological-control orchard. In only one set of eggs exposed in the commercial orchard did the parasitization exceed 10 per cent. These eggs were exposed from August 1 to 4, and 35.3 per cent were parasitized, as compared with 28.8 per cent in the biological-control orchard. On August 17 another set of eggs, placed on the same trees and left until August 20, gave 2.1 and 28.7 per cent parasitization, respectively. Apparently the spray ap-

plied to the commercial orchard on August 4 reduced the activity of *Trichogramma* considerably. This spray consisted of 3 pounds of commercial nicotine bentonite and ½ gallon of oil to 100 gallons of water.

Table 1.—Field parasitization of codling moth eggs on cellophane by *Trichogramma*.

Orchard and Date of Exposure	Eggs Exposed	Eggs Parasitized
	Number	*Per cent*
1938		
Biological-control:		
June 11–July 2	3,473	28.0
July 23–August 30	1,248	27.3
Commercial:		
June 11–July 2	3,617	8.0
July 23–August 30	1,344	5.4
1939		
Biological-control:		
May 22–July 4	915	10.6
July 31–August 27	366	7.7
Commercial:		
May 22–July 4	923	9.5
July 31–August 27	319	3.0
1940		
Biological-control:		
June 18–25	132	4.5
August 9–September 2	334	4.2
Commercial:		
June 18–25	131	3.1
August 9–September 2	353	5.4

In the biological-control orchard there was very little difference in the amount of parasitization between the first- and second-brood eggs. In the commercial orchard parasitization of second-brood eggs in 1938 and 1939 was appreciably lower than that of first-brood eggs, but in 1940 there was a slight increase in the parasitizaton of second-brood eggs over that of the first brood. It is believed that the sharp decline in parasitization of the second-brood eggs in 1938 and 1939 may be attributed to the intensified spraying in the commercial orchard at the time of second-brood oviposition. In 1940 one spray was applied during this period, and this was attended by a slight increase in parasitization. However, only 4 rows were treated under good conditions for nicotine spraying, the other 13 rows being sprayed on windy and rather cool days, when conditions were not suitable for effective application of nicotine sprays.

PARASITIZATION OF LARVAE IN BANDS.—Twenty trees, distributed throughout the two orchards and each having a good set of fruit, were selected for band-collection studies. The same trees were not used in successive years. Two-inch corrugated-paper bands were placed about the trunk and main lateral branches, and were removed periodically for examination. A record was kept of the larvae, pupae, parasitized larvae, larvae or pupae that had been attacked by predators, and diseased larvae. All uninjured larvae and pupae were retained for emergence of parasites, and the results of rearing this material to the adult stage are given in table 2.

It will be noted that the parasitization was low in both orchards, the highest being 5.7 per cent in the biological-control orchard in 1939, while in the commercial orchard the figure was less than 1 per cent in 1938 and 1939. *Ascogaster quadridentata* Wesm. was the dominant parasite in the biological-control orchard, where it was responsible for 94 per cent of the total parasitization during the three years. This percentage includes the *Ascogaster* attacked by *Perilampus capitatus* Smulyan. In 1939, 15.7 per cent were destroyed by this secondary species. Only 34 other specimens of parasites were reared from the material in the biological-control orchard, these being *Macrocentrus instabilis* Mues., *Tritneptis hemerocampae* Gir., *Bassus carpocapsae* Cush., *Microgaster ecdytolophae* Mues., *Eubadizon pleurale* Cress., *Ephialtes aequalis* (Prov.), *Ephialtes* n. sp., *Phanerotoma tibialis* (Hald.), *Mesostenus gracilis* Cress., *Glypta rufiscutellaris* Cress., and *Hyposoter* sp.

Parasite species collected as adults in the band cage, but not reared from isolated cocoons, were *Calliephialtes variatipes* (Prov.), *Mastrus carpocapsae* (Cush.), *Pristomerus ocellatus* Cush., *Endasys subclavatus* (Say), *Hemiteles mellicornis* Ashm., and *Lixophaga variabilis* (Coq.).

In order to ascertain whether the small parasitized larvae leaving the fruit would seek hibernating places before reaching the lower bands, 200 small pieces of corrugated paper were fastened around the twigs immediately back of infested fruit in each orchard in 1938. Seven collections in the biological-control orchard yielded a total of 564 stages, of which 5.2 per cent were parasitized, while from the large lower bands on the main branches of the same trees 9 collections yielded 2,276 stages, of which 5.36 per cent were para-

sitized. In the material from the small bands and the large lower bands 28.6 and 25 per cent, respectively, of *Ascogaster* were parasitized by *Perilampus*.

In the commercial orchard 7 collections from the 200 small bands yielded a total of 221 stages, of which only 1 was parasitized. From the large lower bands of the same trees 9 collections produced 1,353 stages, of which only 3 were parasitized. The records from both orchards show that the small bands placed back of the infested fruit collected no more small parasitized larvae than did the large lower bands.

sitization of larvae from the drop apples in the two orchards thus corresponded very closely to that of larvae from the large corrugated-paper bands.

In 1939 applies containing codling moth larvae were selected at random from both orchards for rearing observations. They were cut open, the live larvae were removed, and each larva was placed on a clean, uninfested apple in a jelly glass. A piece of corrugated paper was placed in each glass so that when the larva matured it could spin a normal cocoon. Six collections were made between June 26 and

Table 2.—Parasites reared from codling moth larvae and pupae collected on bands.

Orchard and Year	Total Stages	Total Parasitization	Parasites Reared				
			Ascogaster	*Perilampus*[1]	*Macrocentrus*	*Bassus*	*Others*
	Number	*Per cent*	*Number*	*Number*	*Number*	*Number*	*Number*
Biological-control:							
1938	7,474	4.6	306	23	3	2	7
1939	2,431	5.7	107	20	10	0	2
1940	3,685	2.9	87	9	5	1	4
Commercial:							
1938	2,184	0.9	13	1	0	6	0
1939	378	0.8	1	0	0	2	0
1940	440	2.5	4	0	0	7	0

[1] Parasite of *Ascogaster*.

Parasitization records for larvae obtained from bands placed above and below tanglefoot on trees in 1938 showed that 4.23 per cent of the descending larvae and 3.30 per cent of the larvae from the ground were parasitized.

PARASITIZATION OF LARVAE IN DROP APPLES AND IMMATURE FRUIT.—Drop apples from the banded trees were gathered and cut open to determine whether the parasitization of the larvae from these apples was higher than that of larvae obtained on the bands. The larvae found were placed in jars with fresh, uninfested apples. Between July 12 and the first of October 926 larvae were obtained from apples collected in the biological-control orchard and only 356 larvae from those in the commercial orchard. The drop apples collected in the biological-control orchard revealed a parasitization of 5 per cent of the larvae by *Ascogaster*. Only a single specimen of one other primary parasite, *Macrocentrus instabilis*, was obtained. The drop apples in the commercial orchard showed a parasitization of 2.2 per cent of the larvae by *Ascogaster*. The para-

September 18, and 573 larvae from the biological-control orchard and 567 from the commercial orchard were placed on clean apples.

A total of 72.8 per cent of the larvae from the biological-control orchard and 75.3 per cent from the commercial orchard formed cocoons. When reared through to the adult stage, the material from the biological-control orchard showed a parasitization of 15.9 per cent, 15.2 per cent by *Ascogaster* and the remainder by *Bassus*. Only 4.0 per cent of the material from the commercial orchard was parasitized, 1.46 per cent by *Ascogaster* and 2.56 per cent by *Bassus*. This higher rate of parasitization as compared with that obtained from the band records for 1939 (see table 2) indicates that a large number of the parasitized larvae do not reach the corrugated bands on the trunk and main lateral branches. The percentages of parasitization recorded from the small bands just back of the infested fruit, the large corrugated bands, and the drop apples corresponded very closely in the two orchards, but were considerably lower than

of the larvae collected from infested fruit on the tree. Therefore, to obtain the most accurate figure for parasitization by *Ascogaster*, the larvae should be taken from infested fruit and reared to the adult stage.

PREDATORS ATTACKING THE EGG.—When the codling moth eggs, laid on cellophane, that were placed in each orchard for parasitization by *Trichogramma* were examined, the number of eggs that had been fed on by predators was also recorded. The percentage of eggs thus destroyed is given in table 3. Although the percentage attacked in 1939 was greater than in the other two years, the difference is not significant.

Table 3.—Percentages of codling moth eggs laid on cellophane that were attacked by predators.

PERIOD EGGS WERE EXPOSED	ORCHARD	1938	1939	1940
May 22–July 4	Biological-control	—	18.5	—
	Commercial	—	6.8	—
June 18–25	Biological-control	—	—	7.6
	Commercial	—	—	7.6
July 23–Aug. 30	Biological-control	3.4	21.9	—
	Commercial	1.3	16.6	—
Aug. 9–Sept. 2	Biological-control	—	—	9.3
	Commercial	—	—	8.5

Search was made for egg predators on the leaves, but no direct evidence of feeding was observed in 1938. In August 1939 the predation averaged 15.1 per cent in the biological-control orchard and 15.6 per cent in the commercial orchard. In August 1940 predation of eggs on the foliage in the biological-control orchard was 4.8 per cent and in the commercial orchard 6.6 per cent. The actual predation was probably much higher, as eggs destroyed by predators are very difficult to see on the foliage.

The only predator observed feeding on codling moth eggs in the orchard in 1939 and 1940 was a small black thrips, *Leptothrips mali* (Fitch). Observations and experiments with this thrips are discussed in the following section. Coccinellid larvae confined with codling moth eggs did no feeding; adults of *Anatis quindecimpunctata* (Oliv.), *Hippodamia convergens* Guer., and *Cocinnella novemnotata* Hbst. fed on eggs in confinement, but adults of *Cycloneda munda* (Say) and *Scymnus indutus* Csy. failed to do so. Neither newly hatched nor older chrysopid larvae fed on codling moth eggs.

Leptothrips mali.—Both nymphs and adults of *L. mali* were observed many times feeding on codling moth eggs in the orchard and in confinement. Bailey (1940) gives a complete record of the history, economic importance, biology, distribution, and host plants of this thrips,

Table 4.—Populations of *Leptothripa mali* on apple foliage in 1939 (2-hour counts).

DATE	BIOLOGICAL-CONTROL ORCHARD		COMMERCIAL ORCHARD	
	Adults	Nymphs	Adults	Nymphs
June 6	69	158	35	39
10	—	—	Lead arsenate-lime spray	
12	67	156	7	62
15	—	—	Lead arsenate-lime-copper sulfate spray	
18	89	236	21	33
21	—	—	First mowing of cover	
26	First mowing of cover		—	—
July 7	323	45	408	13
14	Second mowing of cover		—	—
17	—	—	Second mowing of cover	
31	276	152	356	156
Aug. 1	—	—	Nicotine-summer oil spray	
7	210	224	172	172
25	16	168	22	152
Sept. 18	—	8	—	8

which is known as the black hunter. However, there apparently has been no previous published record of its feeding on codling moth eggs.

The thrips were observed not only on apple foliage but also on the flowers of the common perennial daisy and other plants. Population counts were made periodically in 1939 and 1940, to determine the relative number of thrips on apple foliage and on daisy flowers in both orchards, and to determine the effect of sprays and of mowing the cover.

The counts of thrips on apple foliage during 1939 are given in table 4, and the counts on daisy flowers during June of that year in table 5. These tables show the effect of spraying on the population of thrips as well as on the migration of this insect from daisy and other weeds to apple foliage. The lead arsenate sprays applied on June 10 and 15 in the commercial orchard brought about a decrease in populations of both nymphs and adults, whereas in the biological-control orchard the population was increasing rather sharply. This increase, which was concurrent with a sharp decrease in the number of adults in daisy flowers after the peak of daisy bloom had passed, suggests the beginning of a seasonal migration of thrips adults from daisy flowers to apple foliage.

The most pronounced increase on apple

foliage was from June 18 to July 7. This was probably due to accelerated migration induced by the mowing of the cover crop in both orchards in the latter part of June. The second mowing of the cover crop in the middle of July helped to maintain the peak of adults from July 7 to 31. Very few nymphs were found in the daisy flowers at this time, though large numbers of adults were in them early in the season. However, there was a gradual increase of nymphs on the apple foliage, unless retarded by sprays, and this increase was augmented by the movement of adults from the daisies to the apple foliage for egg laying.

On August 1 a summer-oil spray containing nicotine was applied to the commercial orchard. It definitely retarded the thrips population. There was a very sharp drop in the adult population and a slight increase in the number of nymphs. In the biological-control orchard there was also a decrease in adults, but not so great as in the commercial orchard. The increase in nymphs at this time was much greater in the biological-control orchard, despite the fact that prior to the application of the spray there was a much higher adult population in the commercial orchard.

From June 6 to 18 the average number of thrips collected in the biological-control orchard was 258 per 2-hour count. The predation of first-brood eggs placed in this orchard during this period was 16.4 per cent. During the same period the average number of thrips in the commercial orchard was 66, and 6.21 per cent of the eggs placed there were destroyed. Thus, more than four times as many thrips were found in the biological-control orchard and almost three times as many eggs were destroyed by them as in the commercial orchard. From July 31 to August 25 the average number of thrips collected in the biological-control orchard was 349 per 2-hour count, and the attack on second-brood host eggs exposed during this time average 21.9 per cent. In the commercial orchard during the same period the average number of thrips collected was 344, and attack on host eggs amounted to 16.6 per cent. Thus, first-brood eggs were fed on as extensively as those of the second brood, and this may be correlated with the thrips population on apple foliage during these times.

In 1940 the same trends observed in 1939 were evidenced, except that the migration from daisy flowers to apple foliage was considerably lighter. Although the population of thrips in daisies was estimated to be about three times as great in the commercial orchard, the migration to apple foliage a few days after mowing resulted in an increase of 242 per cent in the commercial orchard, as compared with an increase of 540 per cent in the biological-control orchard. These data furnish another illustration of the adverse effect of a nicotine spray, which was applied in the commercial orchard about the time of mowing.

Table 5.—Numbers of *Leptothrips mali* on field daisies in 1939 (2-hour counts).

Date, June	Flowers	Adults	Nymphs	Adults per 100 Flowers
	Commercial Orchard			
6	391	260	15	70
12	110	29	0	26
18	113	25	0	22
	Biological-Control Orchard			
6	301	141	2	47
12	115	40	1	35
18	111	38	0	34

In 1940 the presence of *Leptothrips mali* on apple foliage in larger numbers concurrently with the second brood of the host than with the first brood was not accompanied by an appreciable increase in the number of eggs destroyed, as was the case in 1939. This is probably because the thrips migrated to apple foliage in 1940 between the first- and second-brood oviposition periods, and also because of a greater concentration of alternate host insects (leaf roller eggs and red mites) on apples in 1940. The observations during these two years suggest the possibility of slightly increasing biological control of the codling moth by timely mowing ofthe cover crop.

Predatism Under Bands.—When the corrugated-paper strips around the trunk and main lateral branches of the trees were removed to obtain the larvae and pupae for parasite records, a count was also kept of the larvae and pupae that had been attacked by predators. In 1939 the average predatism was 7.87 per cent in the biological-control orchard and 4.99 per cent in the commercial orchard. Most of the predators were ants, especially

Solenopsis molesta (Say). In 1939 the averages were 14.40 and 8.68 per cent, respectively. However, in the period between July 27 and August 25 the five bands removed in the biological-control orchard showed an average predation of 25 per cent, the highest for any one date being 34 per cent. During the same period in the commercial orchard the average predation was 23 per cent, the highest being 26 per cent. In 1940 the averages were 3.6 and 4.0 per cent, the lowest recorded in the three-year period.

When the bands were removed from the trees, a great number of cocoons destroyed by predators were observed, but the exact species responsible were unknown. However, in a number of instances the predator was feeding on the larva or pupa within the cocoon. The number of larvae observed being attacked plus the cocoons showing the small characteristic holes caused by *Solenopsis molesta* amounted to 38.3 per cent of the cocoons found attacked in the biological-control orchard in 1938, 64.2 per cent in 1939, and 42.5 per cent in 1940. In the commercial orchard this species was responsible for 2.56 per cent of the total number of cocoons consumed by predators in 1938, 41.9 per cent in 1939, and 4.8 per cent in 1940. In the biological-control orchard 0.8 per cent of the total predatism in 1939, and 14.3 per cent in 1940 were observed to be by adults of the ostomid *Tenebroides corticalis* (Melsh.). In the commercial orchard 3.2 per cent of the larvae in 1939 and 14.3 per cent in 1940 were observed being attacked by this species. On only a few occasions have cantharid larvae, *Chauliognathus pennsylvanicus* (Deg.) and *Chauliognathus* sp., been observed feeding on codling moth larvae within cocoons in the bands.

PREDATISM OF COCOONS ON THE GROUND.—To test the extent of feeding by predators on cocoons that have been spun up on the ground, codling moth cocoons formed in corrugated-paper strips were placed on the soil and under trash in both orchards. From 10 to 25 cocoons were placed under each of 8 to 20 trees in each orchard. The cocoons were distributed from the trunk to the outer circumference of the branches. They could be left out for weeks in the fall and early in the spring, but in warmer seasons they were usually exposed for only 4 to 7 days. Approximately 4,000 cocoons were used in each orchard.

The rates of predatism obtained in these tests indicated that very close to 100 per cent of the cocoons placed in each of the orchards would be destroyed by predators if they were allowed to remain exposed to the natural enemies for periods equivalent to the normal time spent in that stage.

The cultural practices in the two orchards were practically the same during 1938 and 1939. However, early in the spring of 1940 the ground under the 9 rows of York trees in the commercial orchard was thoroughly disked to control mice, whereas the 13 rows of Ben Davis trees were not cultivated, in order to determine the effect of cultivation on the activity of ground predators.

Cocoons were placed under 27 of the York trees that had been disked and 23 of the uncultivated Ben Davis trees. After 14 to 18 days of exposure, 368, or 62.4 per cent, of the cocoons under the uncultivated trees had been attacked, as compared with only 268, or 48.4 per cent, under the cultivated trees. Soil examinations from these cultivated rows in May and June showed a much lower carabid population than in the other rows of the commercial orchard. That cultivation decreases the activity of ground predators becomes still more significant from the predation records for 1939, when the percentage of predation under the York trees was consistently higher than under the Ben Davis trees.

In order to determine which predators were responsible for the attack, the damaged cocoons were placed in the following five classifications when examined in 1939 and 1940: Large hole in cocoon; medium-sized hole in cocoon; small holes in cocoon; cocoon mostly eaten with only slight remnants left; cocoon entire with dead larva, hard and rusty brown in color, giving the appearance of having been burned. In three of these groups the distinction is rather sharp. It is known that the cocoons with small holes were attacked only by *Solenopsis* and *Monomorium*. Those cocoons in which there is only a slight remnant left may be attributed to the wireworm *Conoderus lividus* (Deg.), the only predator ever observed attacking a cocoon in this manner. Those cocoons that are entire but contain dead, burned

larvae can be attributed to the two ants *Formica fusca* L. and *F. pallide-fulva schaufussi incerta* Emery. Cocoons with large holes may be attributed to predator activity of all the Carabidae in both the adult and larger larval stages and to the larva of *Chauliognathus marginatus* (F.). The group with medium-sized holes represents possible predatism by ants of *Aphaenogaster fulva aquia* (Buckley), *Tetramorium caespitum* (L.) and *Phaidole pilifera* (Roger), as well as some of the smaller carabid larvae and predaceous ostomid larvae.

Analysis of these groupings for 1940 shows that in April and May 65 and 69 per cent of the total destruction of the cocoons in the biological-control and commercial orchards, respectively, was caused by carabid adults and larvae, and by *Chauliognathus* larvae. During July predatism by these species was considerably less, being only 21 and 25 per cent of the total predation in the respective orchards. However, in the fall this type of predatism amounted to 78.3 and 87.1 per cent of the total of the cocoons in the two orchards. During the summer the predominant type of predation was that caused by *Solenopsis* and *Monomorium*. These ants caused 52 and 53 per cent of the total predation in the biological-control and commercial orchards, respectively, while in the spring only 6 and 4 per cent and in the fall 6 and 1 per cent, respectively, were of this type. Thus the percentage of larvae consumed by *Solenopsis* in the summer is usually high enough to overshadow and minimize the role of the carabids in destroying cocoons on the ground.

The following species were occasionally found feeding on cocoons: *Solenopsis molesta*, *Monomorium minimum* (Buckley), a wireworm, probably *Conoderus lividus*, *Tetramorium caespitum*, *Aphaenogaster fulva aquia*, the larva of *Chauliognathus* sp., a malachiid larva, *Collops quadrimaculatus* (F.), a staphylinid (which escaped), *Deroceras laeve* (Muller), centipedes, and predaceous mites belonging to the family Parasitidae. Since these predators consume a cocoon very quickly, it is only rarely that their feeding occurs simultaneously with the examination. The importance of the wireworm *Conoderus lividus* as a predator of cocoons hibernating on the ground early in the spring is indicated by its being responsible for approximately 10 per cent of the predation in the biological-control and 5 per cent of that in the commercial orchard.

Although *Formica fusca* was never observed to attack cocoons, the percentage of predation of cocoons placed on the ground close to a colony of these ants was much higher than in cocoons farther away. The empty cocoons had large holes, typical of the kind made by *F. fusca*. In general, the proximity of cocoons to colonies of *Aphaenogaster*, *Tetramorium*, *Monomorium*, and *Solenopsis* usually resulted in a high predation of the type attributed to these ants.

On October 25, 1940, 40 corrugated-paper strips, each containing at least 5 codling moth larvae, were pinned on 20 trees in the biological-control orchard and screened with half-inch mesh hardware cloth to protect them from birds. The same number of strips were placed in the commercial orchard, and both sets were left on the trees until late in April. In the biological-control orchard 219 codling moth stages were recorded, 11 of which had been attacked by predators. In a total of 217 stages from the commercial orchard only 3 had been attacked by predators. This experiment showed that there was practically no predaceous attack on larvae within the cocoons on the trees during the winter and the early part of the spring. The strips could not be left beyond the date indicated because a great many larvae had changed to pupae. Ants of the species *Formica fusca* were observed crawling up the trunk and limbs of many of the trees containing the strips. Later observations showed that *F. fusca* attacks not only naked codling moth larvae but also larvae within the cocoons, often killing them without visibly damaging the cocoon.

Codling moth cocoons in corrugated paper were also placed in trees in each orchard in July and August. Predatism in the biological-control orchard amounted to 25 per cent and in the commercial orchard 28 per cent. Although only a few cocoons were used, the experiment indicated that a greater percentage of cocoons were attacked by predators in the summer than in the winter or spring, when they were exposed for a longer period.

SOIL EXAMINATIONS FOR PREDATORS.—

In order to compare the number of ground predators in the two orchards, soil examinations were made, and two types of cages were used. The top inch of soil taken from one quarter of an area 10 feet in radius from the trunk of the tree was run through a mechanical soil sifter. In April and May 1938, 12 such examinations were made, 4 in the commercial orchard and 8 in the biological-control orchard, 4 if which were of soil under mulched trees and 4 of soil under unmulched trees. In the commercial orchard 72 Carabidae were found; in the biological-control orchard 74 were found under the mulched trees and 76 under the unmulched trees. In July and August 13 examinations in each orchard gave an average of 57 Carabidae per examination in the biological-control orchard as compared with 41 in the commercial orchard.

Table 6.—Number of predators collected in soil examinations and traps in two orchards, 1938–40.

SPECIES	COMMERCIAL	BIOLOGICAL-CONTROL
Carabidae:		
Agonoderus indistinctus Dej.	2	6
Agonum punctiformis (Say)	8	41
sp.	3	5
Amara muscula (Say)	68	19
sp.	197	427
Amphasia interstitialis (Say)	1	13
Anisodactylus (*Gynandrotarsus*) *agricola* Say	26	30
duleicallis (Laf.)	8	0
rusticus (Say)	63	75
sp.	7	0
Calathus gregarius Dej.	30	41
opaculus Lec.	314	358
Calosoma calidum (F.)	11	3
Chlaenius tomentosus (Say)	4	1
Colliuris pennsylvanica (L.)	6	3
Dysidius mutus Say	3	5
Evarthrus furtivus Lec.	0	6
sp. near *sodalis*	0	16
Harpalus caliginosus (F.)	57	14
compar Lec.	2	12
convivus Lec.	5	1
Harpalus dichrous Dej.	5	9
erythropus Dej.	6	9
faunus Say	102	46
pennsylvanicus Deg.	301	288
Percosia obesa (Say)	1	7
Poecilus lucublandus Say	13	35
Scarites subterraneus F.	5	1
Stenocellus rupestris (Say)	1	13
Stenolophus conjunctus (Say)	12	11
Tachistodes pauperculus (Dej.)	4	15
Miscellaneous carabids	30	31
Elateridae:		
Conoderus lividus (De.) adults	33	35
larvae	47	102
Cantharidae: *Chauliognathis* sp.	79	93
Ostomidae: *Tenebroides corticalis* (Melsh.)	1	4
Staphylinidae	58	108
Spiders	174	177
	1,687	2,060

In May 1939 two examinations in each orchard showed 12 predators from both places. In September of that year the area examined under each tree was reduced to 9 square feet, and collections were made from 32 such plots in each orchard. These examinations resulted in 189 predators from the biological-control orchard and 171 from the commercial orchard.

In 1940, 40 of the small plots were examined in each orchard, and 545 predaceous insects were taken from the biological-control orchard and 421 from the commercial orchard. The lower count in the commercial orchard was probably the result of the thorough disking given a large part of it early in the spring.

Since the soil-sifting method of estimating the population of ground predators was likely to collect more of the sedentary forms, two trapping methods were used to collect more active insects. One method was by weighting down to the ground large fertilizer bags that had been split open. The mulch that formed under these bags and the high moisture content of the soil provided an attractive resting place for several kinds of ground predators. Ten bags were placed in each orchard, and in 9 examinations from August 7 to September 10, 1938, a total of 118 carabids were obtained in the commercial orchard, as compared with only 60 in the biological-control orchard. This method, however, collected only 12 species of Carabidae, as compared with 26 species taken in the soil-sifting method.

Another trap for ground predators was made by burying tin cans, 6 inches deep and 5 inches in diameter, in the ground so that the top of each can was flush with the soil surface. Eight traps were placed in each orchard in May 1939, and 4 collections yielded 34 carabids in the commercial orchard and 3 tenebrionids and 23 carabids in the biological-control orchard.

The most numerous predators collected in the two orchards in the soil examinations and predator traps during the three seasons are listed in table 6, which shows the relative abundance of each species.

No record was kept of the spiders after the first season. In addition to those listed in table 6 the following species were also encountered:

Carabidae:
Agonum crenistriatum (Lec.)
cupripenne (Say)
placidum (Say)
rulripes (Zimm.)
Amara exarata Dej.
Anisodactylus interpunctatus Kby.
melanopus Hald.
Anisodactylus (*Gynandrotarsus*) *ovularis* Csy.
Apenes sinuate (Say)
Cratacanthus dubius (Beauv.)
Cyminidis planipennis Lec.
Dicaelus ambiguus Laf.
elongatus Bon.
furvus Dej.
Dyschirius globulosus Say
sp.
Galerita janus (F.)
Harpalus nitidulus Chd.
Hellumorpha sp.
Notiophilus semistriatus Say
Patrobus longicornis (Say)
Pterostichus adoxus (Say)
Pterostichus (*Amaseus*) *caudicalis* (Say)
Scaphinotus elevatus F.
Scarites sp.
Selenophorus opalinus Lec.
sp.
Stenolophus sp.
Xestonotus lugubris (Dej.)
Malachiidae: *Collops quadrimaculatus* (F.)
Staphylinidae:
Lathrobium sp.
Quedius sp.
Staphylinus cinnamopterus Grav.
Tenebrionidae:
Opatrinus minimus (Beauv.)
Cleridae:
Cymatodera sp.
undulata (Say)
Enoclerus ichneumoneus (F.)

PREDACEOUS ANTS.—In studying the predaceous ants in the two apple orchards, several experiments were conducted during the three years. Before these experiments are discussed, the information obtained on each species of ant and its relative value as a predator of the codling moth will be summarized.

Solenopsis molesta (Say), the thief ant, has minute yellow workers which are very important as predators of codling moth larvae and pupae within the cocoon. They also attack the naked full-grown larva while it is spinning its cocoon. Codling moth larvae passing near a colony site of *Solenopsis* have been attacked and killed by large numbers of ants within two to five minutes and consumed on the spot. *Solenopsis* is most important, however, as a predator of the cocoon stages of the codling moth.

Formica fusca var. *subsericea* Say, a large black ant, is a very important predator of codling moth larvae seeking hibernation quarters. The larva is subdued by an ant in a very short time, and is then dragged to the colony site and immediately taken below the surface of the soil. Larvae are attacked by these ants on the ground, as well as on the trunk of the trees, where the ants are rather numerous if the foliage is infested with aphids. These ants have also been known to attack the larva within the cocoon by making a large hole in the cocoon and then withdrawing the larva. *F. fusca* often injects formic acid into the larva in the cocoon, thus killing it, and then fails to make a hole and remove the larva. However, its principal role as a predator is in destroying larvae that are seeking places for hibernation.

Formica pallide-fulva schaufussi incerta Emery is a large, reddish-brown ant that runs very rapidly. When it encounters a codling moth larva, the larva is immediately paralyzed and dragged into the nest. These ants are much more active than *F. fusca* and subdue a larva much more quickly. However, they were not nearly so numerous and probably do not influence the codling moth population nearly so much. *F. pallide* was never observed to attack a codling moth cocoon and remove the larva, but all the larvae within cocoons placed near a colony of this species were killed, probably by formic acid injected through the cocoon.

Aphaenogaster fulva aquia (Buckley), a medium-sized reddish ant, attacks both larvae seeking hibernation and those within the cocoons. In attacking a cocoon this ant makes a medium-sized hole through which to withdraw the larva. It does not seem to have the power, as has *Formica*, of weakening its prey by injecting a fluid. Codling moth larvae are capable of freeing themselves of one or two ants, but when three ants become affixed to a larva, its chance of survival is small. These ants are rather clumsy fighters and often hinder each other. However, in many instances a large percentage of larvae released near a colony of *Aphaenogaster* were destroyed before they could make their cocoons.

Tetramorium caespitum (L.) attacks naked codling moth larvae and also larvae within cocoons. It takes three or four ants about 10 minutes to subdue a larva, and then they drag it into their

nest. Larvae released near a colony of *Tetramorium* were usually able to reach the corrugated-paper strip, but later examination showed that most of them had been killed while making the cocoon or after completing it.

Monomorium minimum (Buckley), a minute black ant, attacks naked larvae, but usually has great difficulty in subduing them unless they are weakened or are confined so that they cannot escape. However, when a larva is attacked by many ants of this species it is soon killed. These ants are effective predators of codling moth larvae within cocoons.

Among the species of minor importance, *Pheidole pilifera* (Roger) has been observed to attack both naked larvae and those in cocoons; *Lasius niger alienus americanus* Emery and L. *niger* var. *neoniger* Emery, *Prenolepis imparis* (Say), and *Formica rufa integra* Nyl. attack active larvae only; and *Tapinoma sessile* (Say) and *Crematogaster lineolata* var. near *cerasi* (Fitch) have been found to prey only on the larvae in cocoons.

ATTACK OF ANTS UPON ACTIVE LARVAE.—Codling moth larvae were released, one at a time, 5 feet from the base of a tree and were observed until they entered a hiding place, which was then marked. Forty-eight larvae in the biological-control orchard were watched in this way and 11 in the commercial orchard. Of these larvae 10 were attacked by ants and dragged to the nest and 1 was killed by a spider. When the places where the larvae had stopped were examined 24 hours later, 12 good cocoons had escaped attack, 11 larvae were actually seen being attacked, and 7 empty or partially formed cocoons were found, showing evidence of predatism. Probably a few of the other 29 larvae were able to escape and spin up cocoons, but they were not found.

In 1939 mature codling moth larvae were released in both orchards and observed until they had reached hibernating places or were attacked by predators. The larvae were placed on the ground under the trees at distances from 5 to 12 feet from the trunk and at different points around the tree. A total of 197 larvae were released in the biological-control orchard under 16 trees, and 27, or 13.7 per cent, were attacked and killed by predators. A spider attacked and killed 1 larva, and the other 26 were killed by *Formica fusca*. In the commercial orchard 196 larvae were released under 18 trees, and 33, or 16.8 per cent, were attacked and killed by predators. A spider killed 1 larva, *Monomorium* killed another, and the other 31 larvae were killed by *F. fusca*. At one location 7 of the 11 larvae released were killed by *F. fusca*.

When the larvae were released, it was noted that the trunk of the tree had no particular attraction for them. They would apparently go in any direction and seek hibernation in any suitable place encountered. A total of 343 larvae reached a hibernation place and only 31, or 9 per cent, reached the tree before stopping. These 31 larvae traveled an average distance of 10 feet. This indicates that a large number of the larvae that fall to the ground as exposed larvae or in drop apples spin cocoons in the trash on the ground. A large percentage of the cocoons placed on the ground were consumed.

Observations had been made of predatory attack on larvae seeking hibernating places and also of attack on fully formed cocoons. No record had been taken of predation during the time when the larvae were spinning up their cocoons. To obtain such a record larvae were released within barriers.

Wooden frames 3 feet square were made with three layers of corrugated paper tacked around the bottom and one layer around the outside of the frame, to cover the ends of the paper. The soil was leveled off so that the paper strips rested evenly on the ground, and a small amount of dirt was placed around the outside of the frame. When larvae were released in the center of the frame, some would crawl up on it, and these were replaced in the area until all had entered the corrugations.

Twenty frames were placed in each orchard during the period July 12 to September 15, 1939. Approximately 50 larvae were released in each frame, and the frames were distributed throughout the two orchards, being placed under large trees having no apples or near small reset trees. The larvae were left undisturbed for a week and then examined.

A large number of newly formed cocoons were found to have been attacked by *Solenopsis*. Many of the empty cocoons had one large hole, and many of the partially formed cocoons or webbings contained no larva or pupa. It is known that a codling moth larva may make a partial cocoon and then, if disturbed,

move on and make another. The webbings of larvae disturbed by *Solenopsis* show small characteristic holes. In many instances the total number of larvae, coccons attacked by predators, and webbings found in the corrugated-paper strips exceeded the number of larvae released, and this difference is referred to as a surplus. Therefore, in comparing the number of larvae destroyed from the time they entered the barrier until 1 week later, it is probably best to consider the difference between the number entering the barrier and the number of live larvae or pupae recovered. In the biological-control orchard 980 larvae reached the barrier and 425 larvae and pupae were recovered, a difference of 555, or 56.6 per cent. In the commercial orchard 976 larvae reached the corrugations, but only 162 larvae and pupae were recovered, a difference of 814, or 83.4 per cent.

The foregoing data do not show the number of larvae that were attacked in the early stages of cocoon forming. If the number of webbings and the number of missing larvae are added and the surplus is subtracted from this total, the approximate number of larvae attacked before making complete cocoons is obtained. On this basis 167, or 17 per cent, of the larvae in the biological-control orchard were attacked before making complete cocoons. Since predation of cocoons placed on the soil in this orchard amounted to 42.2 per cent, the total predation was 59.2 per cent. In the commercial orchard 53.2 per cent of the cocoons on the ground and 27.1 per cent of the larvae in the frames were destroyed, making a total predation of 80.3 per cent. In both orchards these figures are very close to those obtained for larvae in the frame barriers.

This experiment shows that a considerable amount of predation on codling moth larvae takes place in the period between the time when they reach suitable hibernating places on the ground and the completion of their cocoons.

Table 7.—Numbers of colonies of the most common species of ants found in the biological-control and commercial orchards, 1939–40.

Species	1938		1939		1940	
	Biological-Control	Commercial	Biological-Control	Commercial	Biological-Control	Commercial
Aphaenogaster fulva aquia (Buckley)	31	2	49	2	135	3
Formica fusca var. *subsericea* Say	40	11	26	16	41	15
pallide-fulva schaufussi incerta Emery	5	1	13	5	27	7
Lasius (*Acanthomyps*) *claviger* (Roger)	24	1	30	7	54	5
Lasius niger alienus americanus Emery	9	5	2	14	14	13
Monomorium minimum (Buckley)	2	3	55	1	36	6
Pheidole pilifera (Roger)	5	2	7	5	21	9
Prenolepis imparis (Say)	2	7	6	6	9	4
Solenopsis molesta (Say)	30	31	197	168	149	104
Tetramorium caespitum (L.)	1	23	5	59	43	69
Miscellaneous species	10	11	8	8	10	1
Total	159	97	398	291	539	236

EFFECT OF SPRAYS ON ANT POPULATIONS.—To determine the relative population of predatory ants and the effect of sprays on them, plots in the commercial and the biological-control orchards were examined during the three seasons. The plots were selected at random throughout the two orchards by using maps. Each plot consisted of the area enclosed by four apple trees, about 36 feet apart; thus, an area of approximately 1,296 square feet was examined in each plot. This ground was gone over thoroughly, and all ant colonies were plotted and sample specimens taken.

A consistently larger number of colonies were found in the biological-control orchard than in the commercial orchard. This is attributed to the cumulative effect of sprays applied in the latter. Eighteen plots were examined in each orchard in 1938, 13 in 1939, and 14 and 10, respectively, in the biological-control

and commercial orchards in 1940. In table 7 are listed the 10 most common species of ants encountered in the two orchards in West Virginia during the three seasons. There were 12 additional species, which were relatively scarce, as follows: *Lasius niger neoniger* Emery, *Lasius niger* var., *Myrmica scabrinodis sabuleti* Meinert, *Tapinoma sessile* (Say), *Polyergus lucidus* Mayr, *Formica pallide-fulva nitidiventris* Emery, *Crematogaster lineolata* var. near *cerasi* (Fitch), *Formica fusca* var. *subaenescens* Emery, *Brachymyrmex heeri depilis* Emery, *Brachymyrmex* sp., *Strumigenys reflexa* Wesson and Wesson, and *Formica rufa integra* Nyl.

In 1938 search for ant colonies was made in 18 locations in each orchard. Approximately the same number of *Solenopsis molesta* colonies were found in each orchard (table 7). However, very few colonies of this species were found in the commercial orchard after the middle of June. Nearly four times as many colonies of *Formica fusca* were found in the biological-control orchard as in the commercial orchard. The 11 colonies in the commercial orchard were all found in June.

Aphaenogaster fulva was much more numerous in the biological-control orchard whereas with *Tetramorium caespitum* the colonies in the commercial orchard greatly outnumbered those in the biological-control orchard. This difference was also noted in 1939 and 1940. *Tetramorium* was rarely found in the same plot with *Aphaenogaster*.

Monomorium minimum was much more numerous in the biological-control orchard in 1939 and 1940 than in the commercial orchard.

A considerable drop in the average number of colonies found per examination was noted after the middle of June. This decrease was much more noticeable in the commercial orchard, and is especially important because it was largely in two species, *Solenopsis molesta* and *Formica fusca*, which are outstanding predators of the codling moth. This decrease was probably due to the frequent sprays and to the kinds of sprays applied in the commercial orchard.

In 1938, from the 18 plots in each orchard, 159 colonies were located in the biological-control orchard and only 97 colonies in the commercial orchard. The biological-control orchard had an estimated 289 colonies per acre as compared with 183 colonies per acre in the commercial orchard.

In 1939, 5 plots in the biological-control orchard were examined for ants between April 25 and May 5, and 64 colonies were found, or a rate of 403 colonies per acre. Between June 21 and July 11, 6 plots in the same orchard yielded 242 colonies, or 1,270 colonies per acre. Examinations of the commercial orchard between May 2 and May 11 yielded 41 colonies in 5 plots, or 275 colonies per acre. Between June 21 and August 9, 6 plots in the same orchard gave 212 colonies, or 1,184 colonies per acre.

Some of the plots examined in June and July 1939 had been examined previously, and *Solenopsis* appeared to be greatly increased. If the number of ant colonies found in in these plots, exclusive of *Solenopsis*, is computed to an acre basis, there were 283 colonies per acre in the biological-control orchard in April and May, and 566 colonies per acre in June and July, or an increase of 100 per cent. In the commercial orchard there were 215 colonies per acre in May, and in the period June to August 363 colonies per acre, or an increase of 69 per cent.

The biological-control orchard had more ant colonies per plot than the commercial orchard, but this difference was not so great as in 1938. If the *Solenopsis* colonies are omitted, the commercial orchard had only 51 per cent as many colonies as the biological-control orchard in 1938 and 68 per cent as many in 1939.

The great increase in the number of *Solenopsis* colonies in the areas that were reexamined in June and July may have been due to the following factors: (1) The date of examination, as by the later date more colonies would have been established naturally; (2) the fact that this species seemed to like hard, compact soil and was often found in or near the roads. Many *Solenopsis* colonies were found under the roots of narrow-leafed plantain. The ground had been disturbed, practically all the large weeds and grass had been pulled out, and plantain had replaced the original cover. This changed the habitat and, as the rain packed the soil, the location was made more suitable for *Solenopsis*.

Because more ant colonies were being found per plot in 1939 than in the previous

year, one plot in each orchard that had been examined in 1938 was examined on July 11, 1939. In the biological-control orchard only 2 colonies of *Formica fusca* had been found in 1938, but in 1939, 11 *Solenopsis*, 3 *Formica*, 1 *Monomorium minimum*, 4 *Aphaenogaster fulva aquia*, and 1 *Tetramorium caespitum* colonies were found. In the commercial orchard only 1 *Prenolepis imparis* and 1 *Tetramorium* colony had been found in 1938, but 12 *Solenopsis*, 1 *Formica*, and 7 *Tetramorium* colonies were found the following year. These data show that a considerable change in the ant population may take place within a given area from year to year. Some of the increase indicated may be due to error of sampling, inasmuch as some small *Solenopsis* colonies may have been overlooked in 1938. However, it is certain that large colonies of *Formica*, *Aphaenogaster*, and *Tetramorium* would not have been missed. This increase of ant colonies in the commercial orchard may explain in part the large percentage of predation obtained in that orchard in 1939.

In 1940, 321 colonies were found in 10 plots in the biological-control orchard and 236 colonies in 10 plots in the commercial orchard. When these totals were compared with the numbers of ants found during the corresponding seasons in 1938 and 1939, it was seen that there had been a slight increase each year in the biological-control orchard. There were 95 colonies of *Aphaenogaster fulva aquia* in the biological-control orchard and only 3 in the commercial. Colonies of *Formica fusca* var. *subsericea*, *F. pallide-fulve schaufussi incerta*, and *Monomorium minimum* were more numerous in the biological-control orchard. However, there were two and one-half times as many colonies of *Tetramorium caespitum* in the commercial orchard. The numbers of *Solenopsis molesta* colonies found in the two orchards in July averaged about the same—that is, approximately 8 colonies per plot. During May and June they had averaged 10 colonies per plot in the biological-control orchard and 12 colonies per plot in the commercial orchard. Therefore, the greatest reduction of this species took place in the commercial orchard.

FEEDING TESTS WITH PREDACEOUS INSECTS.—To supplement field observations feeding tests were made to determine whether certain insects found in the soil were active predators on either naked codling moth larvae or larvae within the cocoons. The insects were placed in jelly jars with tin covers and two-thirds filled with moist soil containing plenty of root fragments and decayed organic matter, so that natural food would be available. Naked codling moth larvae and pupae, as well as cocoons, were placed on the surface of the soil, and examined periodically.

In 1938, 34 separate tests were run with only naked larvae and exposed pupae. Eleven species fed on the codling moth larvae or pupae. In 1939 a total of 125 individual specimens were used in the predator-confinement tests. Either naked codling moth larvae or larvae within cocoons, sometimes both, were placed in the jar with the predator. Many predators failed to feed, and some individuals of a species would not feed while others of the same species fed on several larvae, either naked or within the cocoon. Fifty-five specimens did no feeding, while 70 did some feeding.

The results of two seasons tests gave 18 species that fed on both naked larvae and larvae within cocoons, 10 species that fed only on larvae (or pupae) within cocoons, and 11 species that fed only on naked larvae and exposed pupae. The type of feeding by the various species of predators is shown in the following tabulation (1 indicates attack on larvae or pupae within the cocoon; 2, attack on naked larvae or exposed pupae; and 3, attack on both naked larvae and those within cocoons):

COLEOPTERA

Carabidae:	
Agonum (*Circinalia*) sp.	1
Agonum punctiforme (Say)	2
Amara sp.	1
Anisodactylus (*Gynandrotarsus*) *ovularis* Csy.	3
rusticus (Say)	2
Calathus gregarius Dej.	3
opaculus Lec.	3
Calosoma calidum (F.)	3
sp., larva	3
Chlaenius tomentosus (Say)	3
Colliuris pennsylvanica (L.)	2
Evarthrus sp. near *sodalis*	1
Galerito janus (F.)	3
Galertia sp., larva	2
Harpalus caliginosus (F.)	3
compar Lec.	3
dichrous Dej.	1
erythropus Dej.	2
faunus Say	2
pennsylvanicus Deg.	3
Patrobus longicornis (Say)	3

Poecilus lucublandus (Say)	3
Pterostichus sp., larva	1
Scaphinotus levatus (F.)	2
Selenophorus sp. (*gagatinus* group)	1
Ostomidae:	
Tenebroides corticalis (Melsh.)	1
sp. larva	1
Tenebrionidae: *Opatrinus minimus* (Beauv.)	1
Malachiidae: *Collops quadrimaculatus* (F.), larva	1
Staphylinidae:	
Quedius sp.	2
Staphylinus cinnamopterus Grav.	3
Cleridae:	
Cymatodera undulato (Say)	3
Enoclerus ichneumoneus (F.)	2
Cantharidae: *Chauliognathus pennsylvanicus* (Deg.), larva	3
sp., larva	3
Elateridae: *Conoderus lividus* (Dej.), larva	3
sp., larva	3
HEMIPTERA	
Reduviidae: *Pselliopus cinctus* F.	2

A FUNGUS PARASITE OF CODLING MOTH LARVAE.—While a search was being made for codling moth larvae in orchards in Bridgeton, N. J., in March 1938, many dead larvae were found, their bodies overgrown with a white fungus. This organism was isolated in pure culture by S. R. Dutky and determined as probably *Beauvaria bassiana* (Bals.) Vuill. It was later given the same determination by Vera K. Charles, of the Bureau of Plant Industry.

A small-scale experiment was conducted to ascertain whether the fungus was parasitic or simply saprophytic. Four series of overwintering larvae that appeared healthy and vigorous were treated as follows: In the first series the epidermis of the third ventral abdominal segment was pierced with a fine sterilized needle that carried spores; in the second series the larvae were permitted to come in contact with spores, without any rubbing or friction at the point of contact; in a third or control series the larvae were punctured as in the first, but with a sterilized needle bearing no spores; and in a fourth series the larvae were not treated in any way. After being treated, each larva was placed in a small individual glass vial containing a piece of corrugated paper for cocooning, and the vial was capped with a fine-mesh bronze screen. This small vial was then placed in a larger vial containing wet cotton at the bottom. The larger vial was corked tightly and served as a humidifier. All vials were placed in an incubator at a constant temperature of 86° F. Observations were made in such a manner as to prevent contamination. The inner vials were not opened, and the observer's hands were sterilized with hypochlorite solution after each examination.

The results of these tests revealed that the fungus was definitely pathogenic. The percentages of dead larvae 3, 6, and 20 days after treatment are shown in table 8. All larvae that survived attained the moth stage.

Table 8.—Mortality of codling moth larvae in fungus disease tests.

TIME AFTER TREATMENT	DUSTED	INOCULATED	CONTROLS[1]
Days	*Per Cent*	*Per Cent*	*Per Cent*
3	35	25	0
6	65	55	10
20	90	100	20

[1] Both punctured and untreated controls showed the same percentages.

The inception of infection was outwardly manifested by dark-brown lesions over the epidermis and a weakened condition of the larva. Mummification soon followed as the penetrating hyphae began to consume and displace body tissue. This change soon became outwardly manifested by a white mycelium growth, followed by sporulation. In a few tests larvae showing only a few lesions were able to recover.

Additional tests with slight variations were conducted with healthy larvae that had just spun up in bands. The larvae were kept at room temperature, and only half of them were provided with humidifiers. It was found that the fungus is capable of killing the larvae even when no moisture is provided, but is not capable of producing the external mycelial growth, with its consequent sporulation and dissemination of spores. However, as late as five months after the tests were terminated, mummified larvae from these tests became covered with the typical white mycelial growth whenever moisture was supplied.

A small-scale experiment was conducted in the summer of 1939 to determine whether artificial dissemination of spores would increase the mortality of larvae under field conditions. Twenty petri dishes having a heavy growth of mycelium and spores were obtained by midsummer from

the original pure culture. The spores from 10 of these dishes were incorporated in calcium caseinate dust as a carrier and sticker, and this material was dusted over the trunk and main branches of a tree having a moderate crop and a moderate infestation. A water suspension, made with the spores from the remaining 10 dishes, was sprayed on the trunk and main branches of a tree in another part of the same orchard. The larvae from the bands on these trees were retained separately and kept under the same rearing conditions as the bands from the regular-count trees.

From the bands on the dusted tree 122 larvae were collected, of which 32, or 26.2 per cent, died; whereas from the sprayed tree 90 larvae were collected, of which 33, or 36.7 per cent, died. These figures are in contrast with the low mortality of 9 per cent among 16,508 larvae collected from the regular-band trees, and indicate a significant increase as a result of spore application.

These tests indicate that many mature larvae may die in the field from attack by the fungus *Beauveria bassiana*. Mortality among the younger larvae should be much higher because of the moist medium of their habitat. A high mortality of small, newly hatched larvae has been observed in the biological-control orchard, even on unsprayed apples. In the spring of 1939, particularly, the mortality of first- and second-instar larvae was unusually high. The large number of apples showing stings but no worms indicated that some natural-control agent was operating. The season had been unusually rainy and the complex conditions brought about by the rains were exerting an unfavorable influence. The first-brood infestation counts made by Mr. Gould showed 13,710 worms and 7,382 stings, or a ratio of 1.86 worms per sting. In 1938, a much drier season, similar counts revealed 67,419 worms and 13,805 stings, or a ratio of 4.88 worms per sting. Small-scale experiments were conducted to determine whether this high mortality could be attributed in some measure to the parasitic fungus.

On July 4, 10 dead larvae taken from stung apples were placed in 5 petri dishes into which the culture medium had been poured. These petri dishes were allowed to remain in the dark, cool basement of the laboratory, and examination on July 10 showed that 4 dishes had a mycelial growth of *Beauvaria bassiana*. The growth in these dishes originated in, or centered about, 6 larvae. It is therefore probable that 6 of the 10 larvae had been infected by *B. bassiana*.

Apples containing various-sized live larvae, which had burrowed at least a half inch into the apple, were then collected from the biological-control orchard. Twenty of these applies were sprayed with a suspension made by triturating 4 dead larvae containing a heavy fungous growth in an evaporating dish and diluting to 400 ml. with tap water, 20 others were dusted with spores from 4 diseased larvae, and 20 untreated apples served as a check. All 60 apples were placed singly in rearing jars containing larvae and corrugated bands to allow spinning of cocoons.

Of the larvae in the sprayed apples 11 died before becoming full grown, and of the 9 that became full grown 2 died before attaining the adult stage. Of the larvae in dusted apples 14 died before growth was complete, and 3 of the remaining 6 individuals died later. The total mortality from spraying was 65 per cent and from dusting 85 per cent, which indicates that great numbers of spores sprayed or dusted on the cuticle of an apple are capable of killing larvae already established in the apple.

In another experiment 20 clean apples were sprayed with spore suspension, 20 were dusted, and 20 were held as an untreated check. The spraying and dusting were done in the same manner as in the preceding experiment, and the apples were then placed in jars, each with two fresh eggs on cellophane. Of the larvae in sprayed apples, only three of 29 attained full growth, and one of them died after cocooning, and on the dusted apples only 2 of 26 survived, whereas in untreated apples 15 of 27 reached maturity. These data indicate that ingestion of spores is lethal to newly hatched larvae, and that they are less resistant than larger larvae. It is obvious that the fungus *Beauvaria bassiana* is a natural-control agent of immature as well as of mature larvae.

It is probable that other diseases exert some degree of natural control. Occasionally mature larvae with a fleshy fungous growth emerging from the body were encountered. C. F. Taylor, of the West

Virginia Agricultural Experiment Station, isolated this fungus and determined it as *Isaria* sp. In addition, dead mature larvae showing symptoms that suggested a bacterial disease were sometimes observed. They were usually found in cocoons of normal appearance, and had a deceiving healthy pink color, but were soft to the touch. Later these larvae became flaccid and watery, and their color changed from brown to black.

SUMMARY AND CONCLUSIONS.—Insect parasites and predators exert a strong influence on different stages of the codling moth. The eggs are attacked by *Trichogramma minutum* (Riley), which parasitizes up to 28 per cent of the first-brood eggs in some years, but fails to build up as the season progresses, being less effective against the second brood, though eggs are more numerous at that time. The eggs are also attacked by the nymphs and adults of a predaceous thrips, *Leptothrips mali* (Fitch), which is not a voracious feeder but attacks a wide variety of hosts, thereby minimizing somewhat its value against the codling moth. First-brood eggs are seldom attacked by these thrips, but as the season progresses they migrate from daisy flowers and other cover-crop plants to apple foliage, and the feeding on second-brood eggs is increased.

Parasites have a discouragingly small influence in reducing the larval population. The most common species is *Ascogaster quadridentata* Wesm., which parasitizes only a relatively small number of larvae. However, it was far more numerous in the biological-control than in the commercial orchard.

A number of predators attack the mature larvae while they are seeking places to spin their cocoons. Experiments in 1938 showed that 30 per cent or more of the larvae released were attacked by predators within 24 hours, whereas in 1939 14 per cent were destroyed in the biological-control orchard and 17 per cent in the commercial orchard. Ants were largely responsible for this mortality, *Formica fusca* var. *subsericea* Say accounting for over 90 per cent of the total. *Formica pallide-fulva schaufussi incerta* Emery, *Aphaenogaster fulva aquia* (Buckley), *Tetramorium caespitum* (L.), *Solenopsis molesta* (Say), and *Monomorium minimum* (Buckley) were also important predators of mature larvae. All these species of ants except *T. caespitum* were more numerous in the biological-control orchard, indicating that the spray program in the commercial orchard tended to reduce their populations.

The parasitic fungus *Beauveria bassiana* (Bals.) exerts a small degree of natural control on the larval population in all stages. Laboratory tests showed it to be highly pathogenic when spores of the organism were either dusted upon or innoculated into healthy hibernating or freshly spun-up summer larvae. Small-scale field tests showed that artificial dissemination of spores on the foliage effected a significant increase in mortality. Laboratory tests revealed that spore dust or spray applied to infested fruit prevented the newly hatched larvae from making a successful entrance and also killed the larvae after entry. This fungus is particularly important in cool, wet seasons.

The cocoon stage is probably the most vulnerable from the standpoint of attack by predators. Predation under the bands is high, considering the short time of exposure, and high percentages of cocoons on the ground and in trash are consistently destroyed by predators. The important predators of this stage are the ants, particularly *Solenopsis molesta*, *Monomorium minimum*, *Aphaenogaster fulva aquia*, and *Tetramorium caespitum*.

In general, the adverse effect of sprays on the natural enemies of the codling moth was indicated by the fact that the most important parasites and predators were less numerous in the commercial orchard than in the biological-control orchard. Though the egg parasite *Trichogramma* and the larval parasite *Ascogaster* were not numerous, the parasitization by them was consistently higher in the biological-control orchard. Sprays, especially those containing nicotine, reduced the population of the predaceous thrips. Predatory ants were less numerous in the sprayed orchard, and tests with sprays greatly reduced certain species, especially *Aphaenogaster*.—11-29-46.

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Saratoga Spittlebug Injury to Pine

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Since 1940 small saplings of both red pine, *Pinus resinosa* Ait., and jack pine, *P. banksiana* Lamb., in plantations in many parts of the coniferous forest region of the Lake States have been severely injured. Some naturally established stands, most of them sparsely stocked, have also been injured. Twigs, tops, branches, and whole trees have died, with the injury following a typical top-to-bottom progression and resulting in severe damage on areas of over 100 acres in some stands.

FIG. 1.—Twigs with bark removed showing light (2.5 punctures per sq. cm.) and heavy (12.5 punctures per sq. cm.) injury caused by adult spittle insect feeding. An uninjured twig is also shown.

During the years 1941 to 1943 Secrest (1944) studied the injury in Michigan, after which he concluded that a spittle insect *Aphrophora saratogensis* (Fitch), was the causal agent. He suggested that the injury was caused primarily by the removal of sap by the insects and the girdling effect produced by infiltration of resin into the tissues surrounding feeding punctures. The latter effect blocked the conducting tissues of the xylem and the phloem.

In 1943 A. J. Riker and his associates[2] isolated several fungi from the advancing margins of the progressive browning areas of the cortical tissues of jack pine. Of these, the species that appeared to be most important was identified by M. P. Backus as *Chilonectria cucurbitula* (Curr.) Sacc. The possibility that this fungus might also be involved in causing the injury prompted further study on the etiology. Consequently, mycological studies were conducted in northern Wisconsin during 1944 and 1945 by R. H. Gruenhagen,[3] while in 1944 the writer was assigned to deal with the entomological aspects. The objectives of the study reported in this paper were to determine the nature of the injury caused by the feeding of the spittle insect and the relation of that injury to the dying of the trees.

The study was conducted in a severely injured jack pine plantation of the Nicolet National Forest. This stand was established in 1936 with about 1200 trees per acre. In 1944 the trees averaged 6 to 8 feet in height (range 4 to 12 feet) and the survival was about 75 per cent. Approximately 160 acres of trees in this area were severely injured following the 1944 attack.

NATURE OF INJURY.—Flagging is the first external evidence of injury. First to die are short (2 to 8 cm.), slender (2 to 4 mm. in diameter) twigs located inside the perimeter of the crown and attached to the 2-year old section of the branches. Later, if the feeding has been sufficiently severe, the larger twigs and terminals of both tops and laterals die with the upper portions of the trees usually suffering most. The needles on the dying twigs and branches progress through the color stages of yellow-green, straw, and red. Inside the affected twigs immediately beneath the bark, resin flecks occur in abundance. These result from the feeding of the *adult* spittle insects. (See Fig. 1.) The nymphs do not feed on pine.

Shortly after the stylets of the insect's mouth parts had been withdrawn, the tiny feeding punctures could be detected and easily followed in the inner bark by means of a discoloration which delimited them. It was found that the stylets were inserted directly through to the cambial tissue.

[1] This report contains the results of a cooperative study by the following agencies: The Bureau of Entomology and Plant Quarantine, the Bureau of Plant Industry, Soils, and Agricultural Engineering, and the Forest Service, all in the U. S. Department of Agriculture; the Department of Economic Entomology and the Department of Plant Pathology, of the University of Wisconsin; and the Wisconsin Conservation Commission. The writer gratefully acknowledges the helpful suggestions received from many individuals in these organizations.

[2] Personal correspondence.

[3] It is understood that a paper giving the results of this work will be published in a future issue of *Phytopathology*.

Some punctures, passed into the inner bark more or less tangentially to the xylem.

The first evidence of necrosis occurred within 24 to 48 hours in the inner phloem tissues surrounding each puncture, with death of the adjacent cambial tissue occurring 1 to 2 weeks later. The affected tissues turned brown and, when immersed for several hours in a dilute solution (5 p.p.m.) of neutral red, a vital dye which stains only living cytoplasm, and calcium chloride (0.2 molar), the cells did not accumulate the dye. Simultaneously the tissue at the cambial-xylem interface immediately adjacent to the decomposing part became visibly different from uninjured tissue. It had a silvery opaqueness and, when immersed in the dye solution, the cells accumulated the dye more rapidly than did the adjacent uninjured cells. As each puncture aged, it became increasingly difficult to remove the injured inner bark from the xylem. This fact indicated that, even though they were still alive, the cambial cells had stopped proliferating. When the bark was peeled from the wood, the greater adhesion between the wood and the bark of the injured spots caused a partial separation of the cambial cells from each other, and the actual removal of some of the contents of the cambial cells by the insect feeding may have caused the appearance and the dye-absorption characteristics noted above. After the tissues died resin from the cortical canals involved infiltrated into the necrotic spots.

Subsequently, if the attack was light, the uninjured cells surrounding the injured spots proliferated so as to heal the injury, leaving a small pitch pocket in the wood and another in the cortical tissues.

The area of inner bark destroyed as the result of each puncture averaged 3.1 ± 0.11 sq. mm. (range 0 to 8 sq. mm.) for the 201 observations. To make the determinations easier these data were collected before resin had infiltrated into the cambial tissues.

The initial breakdown of the phloem tissue appeared to be due to salivary toxins injected by the feeding insects plus, possibly, the dehydration resulting from the withdrawal of sap. Observations were made by macerating excised salivary glands and placing the macerated material in contact with the inner-bark tissue, either on the cambial-xylem interface or in small incisions. After 12 to 24 hours the tissues exposed to the salivary material were dead. They would not accumulate the dye (neutral red), and the tissue was soft and disintegrated. When salivary glands were first heated, they did not produce this effect; therefore either the substance responsible was of an enzymatic nature or the effect was due to associated microorganisms. The truth of the latter supposition was doubted, because when tiny chips of necrotic tissue were obtained from the margin between living and necrotic areas of the inner bark of dying trees and were placed on healthy inner bark they did not produce necrosis during the 2-day period of the test.

Table 1.—Location of spittle insect attacks on jack pine trees.

Age of Branches (Years)	Size of Area Examined	Current Season's Punctures per Sq. Cm.
	Square Centimeters	*Number*
Current	338	7.6
1	545	9.7
2	271	2.5
4	105	1.1
6	200	.1
8	121	0

The part played by the fungus in causing the resin infiltration into the tissues was not determined; however, it was observed that when the necrosis began spreading the browned inner bark became rather friable, never heavily resin-soaked.

LOCATION OF INSECT FEEDING.—The spittle insects fed most heavily on the needle-bearing parts of the branches. (See Table 1.) Even the difference between the current and the year-old branches was highly significant ($t=4.48$, $n=74$). This difference, however, occurred only in the area where the insects were extremely abundant. In the area where fewer insects were present, the averages were 1.3 and 1.4 punctures per square centimeter (47 observations) for the current and the year-old branches, respectively. From 4 paired observations it was found that there was no significant difference between the number of punctures on the topmost branches (6.0 per sq. cm.) and on the lowest ones (4.8 per sq. cm.) ($t=1.65$).

The foregoing data, as well as most of those that follow, are for jack pine. Time

was not available to study intensively both red pine and jack pine; however, it was found that where the two species were growing together the red pine was more heavily attacked. For 10 trees of each species sampled, the averages were 5.6 and 2.0 punctures per square centimeter for red pine and jack pine, respectively. The difference was highly significant ($t=6.00$). In another area a similar relationship of the amount of flagging on the two species of pine was noted. Tree survival for the original red pine planting was poor so it had been interplanted with the faster growing jack pine Consequently, at the time of examination both species were about the same height (4 to 5 feet). The average number of flagged branches per tree for 80 randomized pairs of red and jack pine was 3.2 and 0.5 per tree respectively. The difference necessary for significance at odds of 99 to 1 is 0.56 flag per tree.

EFFECT OF FEEDING INJURY ON HOST-MOISTURE RELATIONS.—Studies of the feeding habits revealed that *Aphrophora saratogensis* was extremely voracious, and hence capable of causing a severe drain on the host trees. Observations on this aspect were made indirectly by measuring the quantity of liquid excreted by the insects. They were caged either on twigs in small (2.5 cu. in.) heavily waxed paper boxes or on branches placed in larger (1 cu. ft.) boxes, the bottoms of which were covered with wax paper. At the end of each 24-hour period the excreted liquid could be easily picked up and measured with a pipette. In calculating the results a correction was made for evaporation. This was computed from data collected on the rate of evaporation in check boxes containing no insects. Excreted liquid from the previous day's test was used for the evaporating liquid in the checks.

Using the above-described technique, it was found that each insect withdrew—or, more correctly, excreted—during each 24-hour period an average of 0.36 ± 0.04 cc. of liquid, which had been obtained from an average of 1.0 puncture. The range was 0 to 1.54 cc. for the 53 observations.

In most of the tests the insects were allowed to feed on branches standing in bottles of water; however, for 8 of the observations the small paper boxes were attached to trees in the field. For these the average amount of liquid exuded was 0.25 $\pm$0.06 cc. per puncture, no correction being made for evaporation. If 40 per cent (average for the other tests) is added for evaporation, the average for the field tests was 0.42 cc. With the aid of these data, and the knowledge that the inner bark is 1 to 2 mm. thick and contains moisture equivalent to about 213 per cent of the dry weight (25 observations), the amount of liquid (water and elaborated food) removed as the result of each puncture was found to be equivalent to that contained at any one time in 3 to 6 sq. cm. of inner bark—a very considerable amount.

When the needles on the heavily infested trees became yellowish late in July and early in August, it was suspected that the terminal needle-bearing twigs were suffering from a moisture deficiency. Preliminary observations on the relationship were made in August, and in mid September a more complete study was undertaken. Branches that had been exposed naturally to various concentrations of adult spittle insects were collected. Feeding-puncture counts were then made from both the current and the year-old portions of each branch, and the average was computed. Only the current-year shoot was used for determining the moisture content. Before the shoots were split up to be dried the needles, needle sheaths, and terminal buds were removed and discarded. The moisture determinations were then made in the usual manner, a temperature of 100°–110° C. being used for drying the samples. The results (see Table 2) show that there was an inverse relation between the number of feeding punctures and the moisture deficiency. All moisture determinations are expressed with dry weight of samples as the basis.

The writer is not prepared to say how much of this dehydration should be attributed to sap withdrawal, how much to the reduction in conductivity as the result of resin infiltration into the water-conducting tissues, and how much to the activity of the fungus. A few data, however, were collected on the relation of insect feeding to this dehydration.

For determining the effect of sap withdrawal 2 equal-sized branches were collected from each of 3 trees and immediately placed in water. The following day insects were introduced and allowed to feed on 1 branch of each pair. At the end

of 7 days the punctures were counted and the moisture content of the twigs was determined. During the 7-day period the insects made an average of 80 punctures per shoot, and in so doing excreted an average of 25 cc. of liquid per twig. This was equal to 1.3 puncture per square centimeter. At the end of the feeding period the shoot-moisture content of these twigs averaged 199 per cent, as compared with 219 per cent for the checks ($t=2.60$). For significance at odds of 19 to 1 t should equal 2.78.

In addition to the dehydration resulting from the withdrawal of sap, it was also found that the water-conductive ability was greatly reduced in twigs that were currently heavily fed on by the spittle insect. Five-centimeter segments of 1-year-old branches were attached to rubber tubing through which water was introduced and maintained at a constant pressure of 1.95 pounds per square inch. This was done by using the siphon principle with a water head of 4.5 feet. After precautions had been taken to eliminate air from the system for each test, it was allowed to run 24 hours, during which time the water passing through the segments was collected. The results (Table 3) show that there was an inverse relation between the number of punctures and the conductivity. The reduced conductivity apparently is caused by the resin which infiltrates the dead puncture spots.

Table 2.—Relation of spittle insect feeding-puncture concentration to moisture content of current-season shoots of jack pine.

Branches Sampled	Average Punctures per Sq. Cm.	Moisture Content of Shoots[1]
Number	*Number*	*Per Cent*
13	1.5	160
11	8.3	134
13	12.8	118
5	17.1	101
1	21.2	85

$r=-0.83$, which is highly significant.
$Y=-3.58X+162.6$.
[1] Based on dry weight of samples.

Another observation on this aspect was made by constructing simple potometers by inserting 24-inch branches in small-mouthed jars containing a known quantity of water. The tests were allowed to run 3 to 7 days, after which the amount of water consumed was determined. The data (table 4) show an inverse relation between the number of punctures per unit area and the water consumption. These tests were conducted under shade. Probably greater differences would have been obtained had the branches been exposed to sun.

Table 3.—Relation between spittle insect feeding-puncture concentration and water-conductive capacity of year-old jack pine branches.

Branches Tested	Average Punctures per Sq. Cm.	Water Conducted per Day per Branch
Number	*Number*	*Cc.*
26	1.5	40.2
8	7.6	8.1
9	11.8	1.3
1	15.9	0

$r=-0.55$, which is highly significant.
$Y=-3.86X+44.9$.

The minimum moisture-content threshold for jack pine was not determined, nor could it be found in the literature. Marshall (1931), however, has presented data on moisture content of seedlings of several conifer species. The values he obtained for the critical phase of wilting for red pine ranged from 70 to 87 per cent (average 79 per cent) of the moisture content of healthy plants. In the present study yellowing of needles was the first visible external sign that the life-threshold point had been reached, while internally the necrosis of the inner bark was beginning to spread. Frequently this dying of the inner bark began in the year-old branches, where the insect attack was heaviest (Table 2), and then progressed both basally and distally. In these

Table 4.—Relation between spittle insect feeding-puncture concentration and the water consumption of jack pine branches.

Branches	Average Punctures per Sq. Cm.	Water Used per Day per Branch
Number	*Number*	*Cc.*
26	2.1	9.9
7	6.7	4.3
4	11.8	3.0
1	17.7	3.0

$r=-0.40$, which is significant.
$Y=-0.615X+10.6$.

branches the year-old needles browned before those of the current year. The necrosis began in a few places and was characterized by coalescing of the numerous small dead spots caused by the feeding of the spittle insect.

It is from these spreading necrotic areas of the inner bark that the pathologists consistently recovered the suspected fungus, *Chilonectria cucurbitula*. In the early stages of this spreading necrosis, however, she moisture content of the current season's shoots was very low. For 14 observations the average moisture content was 104±3.4 per cent (range 88 to 129 per cent), while the insect-feeding-puncture concentration averaged 14.8 ±0.88 per square centimeter (range 9.2 to 21.2 punctures). In these branches the decomposition of the inner bark involved only 1 to 2 sq. cm. in any one spot. It was usually limited to the year-old portions, and in no case had the branch been girdled by the necrotic inner-bark tissue.

By expressing the foregoing moisture-content data as percentages of the average value found for the shoots least injured by the insects, so as to make these data comparable with those of Marshall's, the values range from 52 to 76 per cent, with an average of 62 per cent. These percentages, being even lower than those Marshall obtained for red pine, suggest strongly that the moisture content of the shoots of the dying jack pine was close to the permanent wilting point at the time the branches died.

Although it would have been desirable to have critical moisture-content data for jack pine, the comparison given above is of some value, for jack pine and red pine are similar in respect to drought resistance. Data presented by Shirley & Meuli (1939) for six field tests of the drought resistance of 2-year-old transplants of jack pine and red pine show average mortalities of 50 and 52 per cent, respectively. The difference, as analyzed by the present writer, is not significant.

In the numerous depressions present in the area of most severe injury (1 to 2 acres and 20 to 30 feet below the surrounding land) the site was better than on the higher areas; hence more vigorously growing trees were present in denser stands. Since the density of the nymphs' host plants, especially sweet fern, was much lower in these depressions, there was a large supply of pine on which the adult insect population could feed and the trees received less injury. Even though some spittle insects moved into these depressions, the feeding-puncture concentration was less in 1944, averaging 4.2 per square centimeter (5 observations), as compared with 8.2 per square centimer (10 observations) for the upland. Nevertheless, after the 1944 attack, some tops and branches died on trees lower down the slopes, and even in the bottoms of the depressions.

Dehydration and subsequent dying of the tops and branches were probably accentuated by the rather dry period during July and August 1944 (total rainfall deficiency for the 2 months was 3.7 inches, or about 48 per cent), although during May and June there was a total excess of 3.2 inches, or about 43 per cent.

Although most of the writer's effort was spent in studying the moisture relations of the injured trees, the effect of the extraction of elaborated food by the insects and the interference with food translocation resulting from the puncture injuries should not be overlooked. Jack pine trees, like most everygreen conifers, are easily starved to death by removing the food-elaborating system. One complete defoliation, or one defoliation of only the new growth, is fatal if it occurs after shoot elongation is nearing completion (Craighead 1940). In the present study the effect of the injury was similar in that it caused the death of the needle-bearing twigs and was, therefore, comparable to complete defoliation.

RELATION BETWEEN INSECT DENSITY AND INJURY.—When the problem was analyzed from the aspect of insect abundance, several significant observations were made. During the last few years, in several widely separated areas where injury has occurred, *Aphrophora saratogensis* has always been present in large numbers before the trees appeared to be dying. Secrest (1944) reported that this happened in the area he studied in Michigan. The present writer observed the same situation in Minnesota and later in Wisconsin; however, the first population counts were made in 1944 in the area where the injury was severe, and they were compared with similar data collected in relatively uninjured plantations nearby. The latter areas were not free of the spittle insect, but the trees had suf-

fered only light twig flagging.

The adult population was determined by counting the insects observed on the trees during a 5-minute interval. During this time the branches of four 7-foot trees could be examined. The data collected (Table 5) support the previous observations that injury was most prevalent where the spittle insects were most numerous. The puncture counts and moisture determinations were made the latter part of September 1944 and the dead branches and twigs were measured the last week of June 1945.

Table 5.—Relation between abundance of spittle insects and severity of injury to jack pine.

Insects Observed per 5-Minute Period	Feeding Punctures per Sq. Cm.	Branches and Twigs Killed per Tree
Number	*Number*	*Feet*
42.5 (36)[1]	10.6 (53)	52.5 (36)
18.8 (40)	1.8 (31)	.6 (36)
Difference required for significance at odds of 99 to 1		
9.6	2.6	21.2

[1] Figures in parentheses refer to numbers of observations.

Only the adult insects fed on pine. The nymphs formed their spittle masses and fed in the vicinity of the root collars on many species of herbaceous and low-growing woody plants. Transformation of the nymphs to adults was noted on July 2 in 1944 and continued for a period of 1 month; consequently, the insects were most abundant on the pine during July and the first half of August. (Table 6.)

Table 6.—Relative abundance of adult spittle insects on jack pine in 1944.

Period		Observations	Insects Observed per 5-Minute Period
		Number	*Number*
June	16–30	—	0
July	1–15	7	50
	16–31	29	52
August	1–15	25	39
	16–31	28	24
September	1–15	6	15
	16–30	2	1

To check these observations further, two experiments were established. One consisted in keeping the insects from attacking some trees that had been injured —some severely—the previous year in the area of great insect abundance; and in the second experiment insects were caged on vigorously growing uninjured branches in an area free of the injury.

In the first experiment 36 trees 5 to 10 feet high in the area most severely injured were sprayed with an emulsion of technical DDT in xylene (8.3 pounds DDT per 100 gallons of solution) during the first week of July 1944, when the adults were emerging. During the following 2 months population counts were made on a few trees every day or two, and check counts were made at the same time on adjacent unsprayed trees. The puncture counts and moisture determinations were made the latter part of September 1944, and the dead branches and twigs were measured the last week of June 1945. The results (Table 7) show that DDT was effective in keeping the trees relatively free from the insects; consequently, these sprayed trees suffered little injury, even though they had been injured rather severely the year before. Previous injury to the trees protected with DDT averaged 20.4 ± 4.0 lineal feet (range 2 to 96 feet) of dead branches and twigs per tree as a result of the 1943 insect attack. During the autumn of 1944 the dead parts were covered with numerous perithecia of the fungus *Chilonectria cucurbitula*. Thus, the fungus was present in these dead branches, and yet in no case did any additional serious injury show up on these DDT-treated trees. On the untreated trees, however, current injury was prevalent. (See Table 7 and Fig. 2.)

Table 7.—Protection of jack pine from spittle insect attack by spraying with DDT.

Treatment	Insects Observed per 5-Minute Period (44 Observations)	Feeding Punctures per Sq. Cm. (10 Observations)	Moisture Content 1944 Shoot[1] (5 Observations)	Branches and Twigs Killed per Tree (36 Observations)
	Number	*Number*	*Per Cent*	*Feet*
Sprayed with DDT	3.2	0.3	169	0.2
Unsprayed	38.9	8.2	122	52.5
Difference required for significance at odds of 99:1	8.7	2.7	36	21.2

[1] Based on dry weight of samples.

In the second experiment the insects were kept in cages during the last few days of their nymphal life; therefore the adults did not have a chance to feed on any pine, either diseased or healthy, be-

fore they were introduced into the cages with the healthy branches. The screen cages were of the sleeve type, 8 inches in diameter and 2 feet long. They were slipped over the branches and the attached cloth sleeves were closed at both ends. The average length of branches and twigs enclosed in each cage was 14.5 feet. Half the branches used were the top portions of trees about 3 feet tall, whereas the remainder were lower side branches of 12-foot trees. Insect mortality was heavy in these small cages. After 2 weeks 32, 42, 58, 76, and 76 per cent of the insects were dead in the 5 groups of 4 replicated cages that originally contained 10, 30, 60, 100, and 200 insects per cage, respectively. Mortality of the insects in the cages on the smaller trees averaged 29 per cent less than that for the insects on the lateral branches of the larger trees. Notwithstanding this relatively short period of life in the cages, the insects lived and fed long enough to cause the injury shown in table 8. Here, again, there was a direct relation between the number of insects and the amount of injury.

FIG. 2.—Tree protected by spraying with DDT. The trees in the background show the injury suffered by those untreated.

Even though the insects had not fed on injured pine before being introduced in the cages, perithecia of the fungus *Chilonectria* were present on the dead portions of some of these caged branches the following summer (1945). In none of the 20 branches caged with insects, did the injury continue down the branch below the limit of the cage up to July (1946), when the final reading was made. (See Fig. 3.)

Fifty-five per cent of the twig mortality on the caged branches occurred during the latter part of the summer following the insect feeding, and the remainder between October 1944 and mid-June 1945. These data are based on lineal measure-

FIG. 3.—Tree on which adult spittle insects were caged. Killing was limited to the parts enclosed in the cage.

Table 8.—Injury to jack pine following exposure to various concentrations of spittle insects.

CAGED BRANCHES	INSECTS PER FOOT OF TWIGS	LENGTH OF TWIGS KILLED PER CAGE
Number	*Number*	*Feet*
4	0	0
11	2.2	2.0
5	6.8	7.6
4	13.0	12.4

$r = 0.74$, which is highly significant.
$Y = 0.897X + 0.48$.

ments of the dead and living portions of each branch in the fall and again the following summer. The injury was more severe on the tops than on the laterals. On none of the 4 branches of which all the caged portions were completely dead in October did any further injury develop. The final observation was made the last of June 1946. Moreover, all the injured trees and branches continued growing from the lower uninfested, hence uninjured, side branches and by 1946 this growth had largely replaced the killed portions.

DISCUSSION.—In every phase of the study pine injury was always found to be correlated with the severity of spittle insect attacks—the heavier the feeding, the greater the injury. The feeding was concentrated on the needle-bearing portions of the branches, and those were the parts that died first. Trees in the area of great insect abundance remained uninjured when they were protected by spraying with DDT, whereas the unprotected trees suffered severely. The greater the number of spittle insects present in cages on vigorously growing branches of trees in an area where the injury was absent, the greater was the injury to those branches. As the injury developed, the most apparent disturbance was in the moisture relations of the current season's shoots. In every observation of this condition the injury was found to be correlated with the severity of insect attack.

Although no studies were conducted on the effect of the extraction of elaborated food materials by the insects or on the interference with food translocation resulting from the puncture injuries, probably these aspects also were of importance.

The fungus *Chilonectria cucurbitula*, on the other hand, was reported by the cooperating pathologist to be constantly present when the spreading necrosis of the inner bark occurred. When necrosis began, however, the moisture content of the affected twigs was much below that found in lightly attacked twigs. Even though the fungus was well established in trees, the injury did not progress after the trees were protected from current insect attack. Similarly, the injury to branches caged with the insects did not extend beyond the limits of the cages. These results suggest that the fungus confines its activity to subnormal tissues and particularly that upon which insect feeding has been heavy. The writer has concluded that feeding by a large population of spittle insect adults was necessary before twigs or branches were killed.

SUMMARY.—This paper presents certain entomological phases of a cooperative study conducted in northern Wisconsin in 1944–45 on the relationships of a spittle insect, *Aphrophora saratogensis* (Fitch), and a fungus, *Chilonectria cucurbitula* (Curr.) Sacc., to injury to jack pine and red pine trees in plantations and in stands of natural reproduction.

The adult insects fed on the needle-bearing portions of the branches. Each insect excreted about $\frac{1}{3}$ cc. of liquid every 24 hours and produced a necrotic spot (3 sq. mm.) in the inner bark. Following the tissue destruction from insect feeding, resin infiltrated into the conductive tissue and apparently interfered with water conduction. After the moisture content of the current season's shoots decreased considerably below that found in shoots with very few insect-feeding punctures, the needles yellowed and the branches died.

The injury, under both natural and caged conditions, was associated with heavy attacks by the spittle insect. Prevention of insect feeding prevented further injury, even though the fungus was established in dead tops, branches, and twigs of the trees, as the result of the previous season's attack.—12-5-46.

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Hosts and Distribution of *Anastrepha serpentina* in Northeastern Mexico

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In recent years adults of the fruitfly *Anastrepha serpentina* (Wied.) have been commonly trapped in the extensive citrus groves of the lower Rio Grande Valley of Texas. In 1934 James Zetek[2] found sweet oranges purchased in the market of Panama City infested with larvae of this insect, and on five occasions since then he has found a few infested oranges in the same market. Later L. F. Greer[2] found several larvae of this insect in two grapefruits from a grove at Mission, Tex., and more recently in grapefruit from Trinidad (U. S. Department of Agriculture 1945). So far as is known, no other infestations of citrus by *A. serpentina* have been recorded and no infestation of other host plants has been found in Texas. Furthermore, the data included in this paper suggest that the adults of *A. serpentina* captured in Texas probably came from Mexico.

Fruits Infested.—Fruits other than citrus known to be hosts of *Anastrepha serpentina* are found from northeastern Mexico to São Paulo, Brazil. Zetek[2] listed star-apple, *Chrysophyllum cainito* L.; small star-apple, *C. panamense* Pittier; *C. panamense* var. *macrophyllum* Standley; sapodilla, *Manilkara zapotilla* (Jacq.) Gilly; sapote, *Calocarpum mammosum* (L.) Pierre; *Labatia standleyana* Pittier; *Zschokkea panamensis* Woodson; mammee-apple, *Mammea americana* L.; and *Dovyalis hebecarpa* (Gardn.) Warb., and mentioned that it had been reared experimentally from alligator-apple, *Anona glabra* L.; tomato, *Lycopersicon esculentum* Mill.; mango, *Mangifera indica* L.; *Spondias lutea* L. (=*S. mombin* L.) sweet pepper, *Capsicum annuum* L.; *Eugenia uniflora* L.; *E. malaccensis* L.; guava, *Psidium guajava* L.; tropical almond *Terminalia catappa* L.; and orange, *Citrus sinensis* (L.) Osbeck. Stone (1942) added *Lucuma obovata* HBK. as a host fruit from Peru, and C. C. Plummer[2] found "chico cimarron" (*Lucuma* sp.)[3] to be a host in Guatemala. *Lucuma caimito* (Ruiz. & Pav.) Roem. & Schult.; *Mimusops coriacea* Miq.; and *Mimusops* sp., included by Costa Lima (1934), and *Calocarpum viride* Pittier, mentioned by Bates (1932), were not given in Zetek's list. Baker *et al.* (1944) cite records which add yellow sapote, *Lucuma salicifolia* HBK., apple, peach, quince, and pear to the list of field-infested fruits, and the experimental infestation of grapefruit, Natal plum, kumquat, and California cherry. A general survey for hosts of fruitflies in northeastern Mexico from 1936 to 1942 resulted in finding infestation in alligator-apple, tempeshquite, *Sideroxylon tempisque* Pittier; jopoy fig, *Ficus* sp.; socavite, *Lucuma standleyana* Pittier; and coma real, *Bumelia laetevirens* Hemsl., in addition to some of the more common host fruits. Infestation in citrus, however, was not found.

On February 24, 1933, M. H. Ford[2] recorded the first capture of *Anastrepha serpentina* in the United States, an adult female taken in a trap in a grapefruit tree near Harlingen, Tex. Shortly afterward two adults were reared from peach grown in Ramos Arizpe, Coahuila, in northeastern Mexico, by personnel of the Mexican Department of Agriculture. Similar records of infested peaches from the same locality were made by inspectors of the Bureau of Entomology and Plant Quarantine in Texas, and later in the same year by other inspectors of the Bureau in the Rio Grande Valley. An unpublished map of the distribution of *A. serpentina* in Mexico, prepared by A. Dampf in 1933, showed no records of its presence in the entire northeastern part of the country. On the Gulf coast the most northern record was near the city of Veracruz. On the west coast it extended north as far as the central part of Sinaloa. The capture of the first fly in the lower Rio Grande Valley of Texas in 1933 and

[1] This work was carried on by the Division of Fruitfly Investigations in cooperation with the Division of Mexican Fruitfly Control, of this Bureau, and la Secretaría de Agricultura y Fomento, Mexico. The writer has had access to data recorded by M. McPhail, J. W. Monk, and C. C. Plummer. He is also indebted to P. A. Hoidale and N. O. Berry for permission to include data recorded by them and other personnel of the Division of Mexican Fruitfly Control. J. Villalon Guevara, of the Secretaría de Agricultura y Fomento, assisted in many ways in Tampico.

[2] Unpublished reports.

[3] Determined by C. L. Gilly and E. J. Alexander.

the several records of infestation in peaches from northeastern Mexico caused some concern, because *A. serpentina* had always been considered a tropical species. At that time little information on the number of peaches grown in northeastern Mexico was available, and the maintenance of a host-free period in Texas from March to October meant the removal of all peaches from the Valley.

In 1934 A. C. Baker[2] made a survey of the situation. Pointing out that *Anastrepha serpentina* is a feeder in sapotaceous fruits, he suggested that *Bumelia* might be infested by it and so be a source of the populations in Texas. He pointed out that the distribution of *B. laetevirens*, or coma real, extends from southern Mexico north into Tamaulipas and might therefore offer a source for northward movement. It was not until 1941, however, that coma real, as discussed in the present paper, was established as a host of *A. serpentina*. It was never convenient to collect this fruit over extensive areas, the only collections made being from near Hacienda de Santa Engracia, Tamaulipas. Collections had previously been made in 1937 and 1939 in March, April, and May, but the fruit was picked when immature and did not prove to be infested. In 1941, six collections of fallen mature fruits were made in June and July, and all collections were found to be infested.

A summary of collections and infestation of the hosts of *Anastrepha serpentina* in northeastern Mexico is given in table 1, and the localities where infested collections were made are shown in figure 1.

Table 1.—Summary of collection of fruit and infestation by *Anastrepha serpentina* in northeastern Mexico.

Host Fruit	Collections				Infested Collections				
	Number	Total Number of Fruits	Date		Number	Total Number of Fruits	Number of Larvae		Number of Flies Reared
			Uninfested	Infested			Total	Average per fruit	
Alligator-apple or corcho, *Annona glabra*, Annonaceae	10	209	Aug.–Oct.	Sept.–Oct.	3	30	17	0.57	15
Jopoy fig or higo jopoy, *Ficus* sp., Moraceae	5	519	Aug., Nov.	May, Aug.	2	112	8	.07	8
Socavite, *Lucuma standleyana*, Sapotaceae[1]	17	467	May–June, Aug., Oct., Dec.	June–Oct.	9	257	18,986	73.87	835[2]
Tempeshquite, *Sideroxylon tempisque*, Sapotaceae[3]	10	557	May, Aug., Oct.	May, Aug.–Oct.	7	277	123	.44	84
Yellow sapote or zapote amarillo, *Lucuma salicofolia*, Sapotaceae	27	298	Apr.–May, Sept., Nov.–Jan.	July, Oct., Dec.	12	153	516	3.37	311
Sapodilla or chicozapote, *Manilkara zapotilla* Sapotaceae	5	89	July	Apr.–July	4	75	208	2.77	78
Sapote or zapote mamey, *Calocarpum mammosum*, Sapotaceae	4	63	Apr., Sept.	May, Aug.	2	52	5032	96.77	?
Star-apple or caimito, *Chrysophyllum cainito*, Sapotaceae	4	85	—	Apr.	4	85	74	.87	46
Coma real, *Bumelia laetevirens*, Sapotaceae	10	7,846	Apr.–May	June–July	6	4,415	168	.04	44
Mammee-apple or zapote domingo, *Mammea americana*, Clusiaceae	2	10	Aug.	Sept.	1	6	44	7.33	40
Peach or durazno, *Prunus persica*, Amygdalaceae	15	828	May–Sept.	Aug.	2	47	?[4]	—	3
Apple or manzana, *Malus sylvestris*, Malaceae	4	563	July–Aug., Nov.	Aug.	1	3	8	2.67	1

[1] Determined by A. C. Baker.
[2] Not all the flies reared are represented here.
[3] Determined by F. R. Fosberg.
[4] Total not determined, as two other species of fruitflies were also recovered.

The surveys made by the writer for the hosts of this fruitfly in this part of Mexico cover roughly an oblong area approximately 400 miles by 250 miles, extending from Brownsville, Tex., to Tuxpan, Veracruz, on the east and from the city of San Luis Potosi to Ramos Arizpe, Coahuila, on the west. Fruits infested with *A. serpentina* were found within this entire range. Seven of the 12 hosts (Table 1) represent 6 genera of the family Sapotaceae. In general, the large tropical fruits, including socavite, yellow sapote, sapodilla, star-apple, sapote, and mammee-apple, are often heavily infested. All

these, with the exception of the mammee-apple, are sapotaceous fruits. The other fruits, such as alligator-apple, jopoy fig, temeshquite, and coma real, are lightly infested. The smaller size of the two last-named fruits may account for this. Available records for peach and apple show these fruits to be lightly infested (Table 1) Peach, however, is also attacked by *A. ludens*, and the Mexican *A. fraterculus* (auct.), and these two species, in addition to *A. serpentina*, have been reared from one small collection of peaches from Aramberri, Nuevo Leon (Fig. 1). The present author and D. F. Starr (1946) found that larvae of *A. serpentina* develop more slowly in peach than in sapodilla.

TROPICAL HABITAT.—Tropical host fruits of commercial importance, such as yellow sapote, sapodilla, sapote, star-apple, and mammee-apple, are found in small dooryard plantings or growing wild in the woods or brush. The other tropical hosts, *i.e.*, alligator-apple, jopoy fig, socavite, and tempeshquite, have been seen only in the wild state, and are of virtually no economic importance. All these fruits grow at sea level from Tampico,

Table 2.—Summary of *Anastrepha serpentina* adults captured at Tampico Alto, Veracruz. Ten traps were maintained in each class of fruit trees.

Month	Number of *Anastrepha serpentina* Adults Taken on—					
	Tree Hosts of *A. serpentina*			Trees Not Hosts of *A. serpentina*		
	Sapodilla	Socavite	Yellow Sapote	Navel Orange[1]	Valdor[2]	Guava[3]
1940						
June	139	6	33	—	10	—
July	233	87	193	31	40	12
August	32	6	8	13	10	22
September	3	3	0	2	1	2
October	12	1	2	2	3	2
November	3	1	0	1	5	3
December	3	0	3	2	1	7
1941						
January	16	1	0	6	4	3
February	7	0	0	3	1	7
March	1	0	0	0	2	0
April	2	0	0	1	0	0
May	26	4	7	18	2	7
Total	477	109	246	79	79	65
June	128	9	10	29	33	15
July	397	—	—	15	50	—
August	37	—	—	0	7	—
September	6	—	—	2	5	—
October	6	—	—	7	6	—
November	13	—	—	12	7	—
December	77	—	—	72	62	—
1942						
January	15	—	—	13	11	—
February	18	—	—	20	3	—
March	1	—	—	0	0	—
April	0	—	—	0	0	—
May	7	—	—	1	0	—
June	17	—	—	11	5	—
Total	722	—	—	182	189	—

[1] Host of *Anastrepha ludens*.
[2] *Zuelania guidonia* (Swartz) Britt. and Millsp., host of *Anastrepha zuelaniae* Stone.
[3] Host of Mexican *Anastrepha fraterculus*.

FIG. 1.—Map of northeastern Mexico. Localities where hosts of *Anastrepha serpentina* were found infested are indicated by a small square block. (Hosts found at Matamoros, Monterrey, Ciudad Victoria, and San Luis Potosi are from markets.)

Tamaulipas, to Tuxpan, Veracruz. Socavite and yellow sapote also grow along the foothills in eastern San Luis Potosi and western Tamaulipas, respectively, at altitudes up to 1000 feet.

Traps of the type illustrated by McPhail (1943), and filled with standard fermenting solution prepared with 80 grams of crude brown sugar per liter of water, were maintained by R. E. Lecroy in several kinds of trees in the vicinity of Tampico Alto, Veracruz (near Tampico, Tamaulipas) for 2 years. Flies were removed from traps every 4 to 7 days, and records were summarized each month (Table 2).

Strict comparisons between specimens of *Anastrepha serpentina* at Tampico Alto

captured in trees of different species cannot be made, owing to differences in growth habits of the trees and to environment, presence or absence of fruit, and other factors. The sapodilla and volador trees were growing in a heavily wooded area which was protected to some extent from strong winds blowing off the lagoon (Fig. 1) about a mile distant. The volador tree has a long, bare trunk and an umbrella-shaped canopy, as compared with the long, subconical canopy of foliage on sapodilla trees. It is conceivable that the environment of a sapodilla tree is more favorable to the fly than that of a volador. The socavite trees were in an open pasture near the lagoon. The yellow sapote trees, although surrounded by brush, were exposed to coastal winds. Navel oranges were interspersed with guavas in rows and were well protected from the wind. It is shown (Table 2) that, in general, most of the flies were captured in both host (especially sapodilla) and nonhost fruit trees during the months of June, July, and August. The capture of flies in nonhost fruit trees probably indicates general dispersal of flies following emergence from puparia formed by larvae upon leaving infested fruit. It is to be expected that flies would congregate in greater numbers in host fruit trees, even though such trees might be barren of fruit.

It is impossible to say positively which fruit might be responsible for the greater number of flies. The star-apple is infested as early as April in Tuxpan, Veracruz, about 100 miles to the south. The principal crop of sapodillas matures in May and June, although some infested fruit has been found in April and July. Infested socavites and yellow sapotes were collected in trapping areas in July and August. The yellow sapote is also infested later in the year, there being records for October in 1939 and 1940. Unfortunately, no collections of this fruit were made in the fall of 1941. The comparatively high numbers of flies captured between November 1941 and February 1942 indicate either that there was much infested fruit in the fall of 1941 or that flies had come into the area, possibly from Tuxpan. Sapotes and mammee-apples were heavily infested there in August and September 1941. The sapodilla is the most numerous and generally distributed host fruit in the vicinity of Tampico Alto and is probably the principal host of *Anastrepha serpentina* in that area. It is not unlikely that some of these fruits can be found throughout the year in more tropical locations.

Tamazunchale, San Luis Potosi, like Tampico Alto, is definitely tropical, and sapotaceous host fruits are not uncommon. Tempeshquite, sapote, and socavite are infested in Tamazunchale (Fig. 1). Socavite is also infested in the vicinity of Ciudad del Maiz, San Luis Potosi. Yellow sapote was found infested at Gomez Farias, Tamaulipas, where large numbers are reported to be growing. In January 1944 a single yellow sapote tree with mature uninfested fruit was seen near Hacienda de Santa Engracia.

SUBTROPICAL AND SEMIDESERT HABITAT.—Data from Tampico Alto show to some extent the habits of the fly in a typical tropical environment. Such environments, however, are far removed from the citrus plantings of the lower Rio Grande Valley of Texas. The greater portion of northeastern Mexico is covered by semidesert vegetation. Luxuriant, markedly different flora grows in the mountain gorges, valleys, and near rivers. Coma real is commonly found growing under such fertile conditions in the foothills on the eastern slope of the Sierra Madre Oriental and adjacent lowlands all the way from near the southwestern boundary of Tamaulipas to central eastern Nuevo León at altitudes ranging from about 500 to 2500 feet. How close to the United States the distribution of coma real extends is not known. W. K. Clore and others have scouted for hosts of fruitflies in a belt 50 to 65 miles wide in Mexico just below the border and did not find coma real. The tree is known to grow in eastern Nuevo León, some 100 to 125 miles from the lower Rio Grande Valley. Unfortunately, it was impossible to make an extensive survey after it was learned that coma real is infested by *Anastrepha serpentina*.

It seems likely that, since coma real is rather generally distributed in the subtropical and semidesert habitat, it may possibly be the most important host fruit. The fruit is small, seldom larger than .75 to .88 inch in diameter, and can support only a few larvae. Nevertheless, tens of thousands of fruits are produced on a large tree, and this may help offset the very light infestations per fruit ob-

served to date. Like many tropical and subtropical trees, not all the coma real trees produce fruit at the same time; therefore ripe fruit can be found throughout the greater part of the year.

Other hosts in this habitat include small numbers of both wild and cultivated peaches growing in the small mountain valleys of Tamaulipas, not far from Hacienda de Santa Engracia. To the north in several arid sections of Nuevo León and Coahuila, the plantings of apple, peach, pear, and quince are more extensive and shipped to border points is generally found infested. Incidentally, in recent years some large pear orchards have been planted at a lower altitude in the foothills (subtropical habitat) in eastern Nuevo León, where extensive citrus groves are also located.

FLIES CAPTURED IN TRAPS AND MOVEMENT OF FLIES.—Numerous glass traps are maintained in the lower Rio Grande Valley of Texas for the purpose of determining when and where fruitflies come into the Valley. Thirty traps were main-

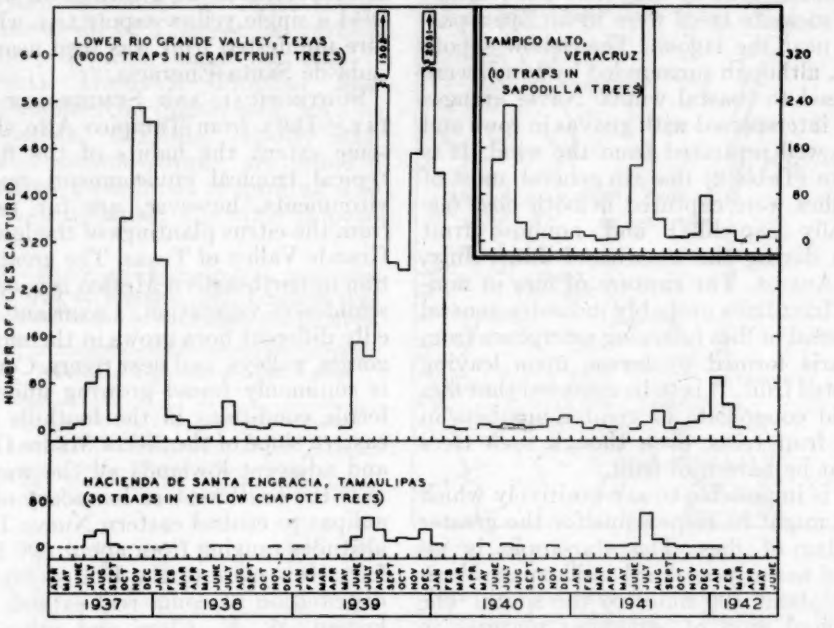

FIG. 2.—Summary by months of number of adults of *Anastrepha serpentina* captured in glass traps during 4- to 7-day exposure periods. Broken line indicates lack of data, and blank spaces mean that no flies were captured. Traps in the Valley were screened to keep out moths, and data from 5695 to 9331 traps were adjusted to 9000 traps.

are found at altitudes ranging from 3320 feet at Aramberri, Nuevo León to 4700 feet at Ramos Arizpe, Coahuila. Infested peaches and apples purchased at the market in the city of San Luis Potosi were reported to have been grown in a similar habitat at Santa Maria del Rio, San Luis Potosi (Fig. 1). Peaches, apples, pears, and quinces from Ramos Arizpe have been reported to arrive in the markets of Matamoros, Tamaulipas, infested with larvae of *Anastrepha serpentina*. During periods of the year when fly captures in the Valley are high, deciduous fruit tained in yellow chapote trees (*Sargentia greggii* S. Wats.) at Hacienda de Santa Engracia for a number of years in connection with studies on this host of the Mexican fruitfly (Plummer *et al.* 1941). Apparently this was also a satisfactory trapping area for *Anastrepha serpentina*, because several large coma real trees were growing in close proximity to trees where traps were placed. A few traps were maintained in sapodilla and other trees in Tampico Alto, Veracruz, by Lecroy, in order to learn about the species of *Anastrepha* there (Table 2). Fermenting brown-sugar

lure was used in all traps. The numbers of adults of *A. serpentina* captured in these traps are summarized in figure 2.

The picture as to the source of adults of *Anastrepha serpentina* captured in the lower Rio Grande Valley is not clear, even though there are several known hosts of the fly in Mexico. The possibility that the populations of *A. serpentina* in Texas originate in citrus fruits is exceedingly remote, because only one infestation has been recorded. It is the practice to inspect all groves throughout the valley each year for larval infestations of *A. ludens*, to determine free movement of fruit from the groves, or to sterilize the fruit after infestation has been found. All larvae discovered are identified. If *A. serpentina* were breeding there in citrus in numbers sufficient to produce the large populations of adults captured, larvae surely would have been discovered more than once during the many years that inspection and certification have been carried on. It seems fairly certain, therefore, that the one infestation in citrus was incidental and had its source in the incoming population.

Adults of *Anastrepha serpentina* were usually caught in greater numbers during two periods of the year, the summer months and the late-fall or early winter months (Fig. 2). Certain phenomena take place only in certain years. For example, in both 1937 and 1939 in the lower Rio Grande Valley high peaks in August are followed by even higher peaks in November and December. Studies on related species of *Anastrepha* show this pattern of fly captures to be typical for populations building up in an area, as shown by the first peak, and emergence from infested fruit in the same area, as illustrated by the second peak. Analogous peaks are shown in data from Santa Engracia in only one of the 2 years—1939. Trapping data for chapote trees for the last 3 months of 1937 are lacking. Since the fly is found in equal abundance in citrus groves, data from nearby grapefruit trees were substituted, and no secondary peak was noted. This fact seems ascribable to differences in locality. A population of flies built up in Santa Engracia in the summer of 1937, but presumably there was little or no host fruit; therefore no secondary peak composed of recently emerged flies materialized. It was supposed in 1937 and 1939 that flies were perhaps breeding in Texas, in Mexico—or in both places—in some host fruit, possibly coma real. As mentioned previously, except for one record in grapefruit, the fly is not known to breed in Texas, and apparently it comes from host fruits growing in Mexico, probably some distance from the border. There is also the likelihood that deciduous fruits growing in the Ramos Arizpe area contribute some flies to the population in Texas.

In the other years of this study there was an increase in the population of *Anastrepha serpentina* in grapefruit trees in the lower Rio Grande Valley in July 1938 and in August 1941, but no winter increase in 1938, perhaps owing to lack of fruit in breeding areas in Mexico. The winter peak in January 1942 may represent flies emerging from off-season fruit in northeastern Mexico, or it may represent a build-up of flies that came from farther south or that had previously been much dispersed in the brush.

It may be that, because of northward dispersal through drift, possibly assisted by wind, just as many adults of *Anastrepha serpentina* would be captured in the lower Rio Grande Valley were no coma real trees present in the intervening subtropical area. A. C. Baker,[2] pointed out in 1934 that various species of fruitflies in Mexico show a tendency to move northward. Maps prepared by the Mexican Meteorological Service show that prevailing air currents over the Gulf Coastal Plain move northward. Mackie (1928) mentioned the possibility of wind drift of the Mexican fruitfly from Mexico to Texas, and called attention to the fact that prevailing winds in Brownsville are from the south and the southeast. The same subject was touched upon by Baker *et al.* (1944).

Data from Santa Engracia in 1938, 1940, and 1942 show the population of *Anastrepha serpentina* to be greatly depressed throughout the year (Fig. 2). There was a build-up in July 1941, but coma real was scarce and no secondary peak was recorded.

The trapping data from Tampico Alto show high peaks in the number of flies captured in the summer months, with the exception of June 1942 (Fig. 2). It is believed that June peaks, representing build-up of population, and July peaks, representing emergence of flies, are close

together, owing to high temperatures and the rapidity with which larvae develop in sapodilla fruit.

SUMMARY.—*Anastrepha serpentina* which is distributed from Texas to Brazil, has been reported infesting grapefruit in Texas and oranges in Panama. In northeastern Mexico the preferred hosts are tropical fruits, and 7 of the 14 fruits found infested belong to the family Sapotaceae, including sapodilla, sapote star-apple, and yellow sapote. Deciduous fruits, including peach, apple, pear, and quince, are also infested. The fly has been reared experimentally from mango, sweet pepper, guava, tomato, cherry, citrus, and certain tropical fruits.

Until the first adult was captured in the lower Rio Grande Valley of Texas in February 1933, *Anastrepha serpentina* was considered a strictly tropical species. Later in the same year infested peaches from Ramos Arizpe, Coahuila, were reported.

Traps filled with fermenting sugar solution were used in Mexico and Texas to observe populations of fruitflies. Traps hung in various tropical fruit trees in Tampico Alto, Veracruz, captured more adults of *Anastrepha serpentina* in June, July, and August than during other months of the year.

Coma real is the only sapotaceous fruit found in the subtropical and semidesert habitat of northeastern Mexico that is known to be infested by *Anastrepha serpentina*. Although coma real is rather commonly distributed in this part of Mexico, it is not known to grow within 100 or 125 miles of the lower Rio Grande Valley of Texas.

Infested peaches, apples, pears, and quinces from the arid highlands of Coahuila and Nuevo León are frequently reported to arrive in the markets of Matamoros, Tamaulipas.

Trap recoveries of adults of *Anastrepha serpentina* in both Texas and Mexico are usually greater during the summer months and the late-fall or early-winter months. The source of the adult flies captured in Texas is not clear. It is possible that they come either from deciduous fruits or coma real growing in northeastern Mexico or from tropical fruits growing farther south. —11-26-46.

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Dr. C. C. Compton and Mr. W. E. McCauley have become associated with Julius Hyman & Company, Inc., Denver, Colorado, as entomologists. Dr. C. C. Compton was connected with the Illinois State Natural History Survey for 24 years. More recently both Dr. Compton and Mr. McCauley were entomologists with Velsicol Corporation, Chicago.

Use of Sulfa Drugs in Treatment of American Foulbrood Disease of Honeybees[1,2]

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The use of sulfa drugs in the treatment of American foulbrood was first brought in a practical way to the attention of American beekeepers by Hasejan & Childers (1944) as the result of experiments started in May of 1942. Their operations were amplified further in the February, 1946, number of this Journal. Since the publication of the original data others have checked the use of sodium sulfathiazole in the treatment of colonies infected with American foulbrood and have reported various results. Johnson & Stadel (1946) experimented with the usual treatments of infected colonies with sulfathiazole in sugar sirup and also tried a solution of sulfathiazole in water alone as a spray and in the water given to infected colonies. Several articles on the use of sulfathiazole have appeared in the bee journals.

While most of the reports have been generally favorable, in some cases the disease has recurred, indicating that the treatment may not eliminate the disease entirely under all conditions. This fact has caused many beekeepers to view the value of this treatment with considerable doubt. However, Foster (1946) reports that the State of Florida is incorporating this treatment in its bee disease control program with the treatment being applied to colonies placed in quarantine and under the supervision of a qualified inspector.

Because of the great amount of interest shown in this treatment and because of the desire of the beekeeping profession to find some efficient method of eradicating American foulbrood without the destruction of the infected combs and colonies, observations were started in May of 1945 to determine the value of sulfa drugs in the treatment of this disease under California conditions. A majority of the observations were made on colonies located near Sacramento, Davis and Winters with beekeepers cooperating and reporting on tests conducted in their own apiaries in other parts of the state. All beekeepers who desired to test the efficiency of sulfa drugs in the treatment of American foulbrood were urged to do so with the cooperation of their county apiary inspector.

The colonies were fed varying amounts of sulfathiazole in sugar sirup of different concentrations and by feeding the drug in pollen supplements. The degree of infection in the treated colonies varied from a few cells to where a majority of the brood was infected and cells in the brood area contained many scales of larvae killed by the disease. As a general rule, the hive equipment was reduced to a point where the colony could adequately cover and protect the combs. No effort was made to remove all of the diseased combs and super combs were either used to make divisions of infected colonies or were replaced if and when the colony strength again warranted expansion of the hives. All equipment of infected colonies was plainly marked to prevent getting the combs mixed up with other hives. The honey was also kept separate from honey extracted from healthy colonies. It was also considered desirable to take precautions against contaminating other combs by using a separate honey extractor.

Chemical analysis studies were started to determine the sulfa content in the brood, royal jelly, bees and honey of colonies given this treatment but have not progressed enough to warrant a report in this paper.

Methods of Feeding.—The sulfathiazole was usually fed by dissolving one-half gram of sodium sulfathiazole in a 10-lb. honey pail of sugar sirup. The concentration of the sugar sirup was varied from 25 to 50 per cent since it seemed evident that the sugar sirup was simply a medium for getting the bees to take the sulfathiazole and in stimulating the bees in their brood rearing activities. In weak or heavily infected colonies, the first feeding was accomplished by pouring the sulfa-sirup directly into the cells of the brood area. Later feedings were given either in entrance feeders or by gravity feeders placed directly over the brood frames.

[1] The sodium sulfathiazole used in these experiments was furnished by the Lederle Laboratories, Inc., Pearl River, New York.

[2] Paper presented on the Richmond Program, Dec. 1946.

OBSERVATIONS ON TREATED COLONIES.—Forty colonies in one group that had been treated since the fall of 1945 were so seriously injured by the effects of arsenical poisoning during the summer of 1946 that the observations had to be discontinued and a majority of the colonies destroyed. The colonies had been fed from 1.5 to 3 grams of sodium sulfathiazole in the fall of 1945 and each was given sirup and pollen supplement containing a half gram of sulfathiazole in January. Examination of the brood on January 26, 1946, indicated no disease in the brood. Examination on March 14 indicated one colony with 16 cells of foulbrood in four combs and one colony the brood of which was 100 per cent infected with European foulbrood. (The latter colony was ultimately destroyed. A microscopic examination of the infection indicated a pure culture of Bacillus alvei.) On May 7, 12 of the colonies were too weak at the time of examination to make satisfactory test colonies and were united. Nine out of the remaining 28 colonies were infected with American foulbrood and one slightly infected with European foulbrood. These 28 colonies had stored considerable surplus honey and were in a flourishing condition. Each of the infected colonies was given a half gram of sulfathiazole in sugar sirup but the nectar flow caused the bees to take the sirup very slowly. Examination of the brood on June 18 indicated that two of the nine colonies found with American foulbrood on the previous examination still had a few cells of disease and three additional colonies showed up with from two to four cells of the disease. These colonies were gathering considerable nectar but each of the diseased colonies was given sulfathiazole in sugar sirup. Evidences of arsenical poisoning were observed on July 20, when 1200 pounds of surplus honey was extracted from the hives. On August 1, eight of the colonies showed up with foulbrood in varying amounts and all were greatly reduced in strength from the effects of arsenical poisoning. An examination of the colonies on August 26 indicated that 12 of them had foulbrood in varying amounts, two colonies being badly infected. All colonies were so seriously injured from arsenical poisoning that they were not normal in bees or behavior after the middle of July and so could not have responded normally to the sulfa-sirup. It was evident that few would survive the poisoning and the tests with sulfathiazole were discontinued.

In this series of observations it was evident that where colonies had sufficient stores of honey in the fall to be carried well over into the spring, fall and early spring feeding of sodium sulfathiazole did not eliminate American foulbrood in all cases. Additional feedings with sulfa-sirup were necessary to keep the disease under control during the build-up of the colony in the spring after surplus honey had been extracted. Later the incoming nectar interferred with the treatment of the colonies in that sulfa-sirup was either not taken down or was not all used in the brood chamber. And finally, the reduction of the colony population and morale from the effects of arsenical poisoning resulted in the ultimate death of a majority of the colonies. During the time of the observations, sacbrood was present to a minor extent in a number of the colonies and was not materially reduced by the feeding of sulfa-sirup. Also, European foulbrood developed in a colony that had been fed sulfa-sirup in the fall and again in the spring to such an extent that the colony was finally destroyed.

ADDITIONAL OBSERVATIONS.—A second series of test colonies was started in May of 1945 with the colonies located on the experimental farm at Davis and near Winters, California. Table 1 indicates a partial history of these colonies to November 1, 1946. In the beginning the colonies were found to be infected in varying degrees and were fed different amounts of sulfathiazole. The location was less favorable for honey production than the previous one and the colonies were moved from Davis to Winters in July to avoid injury from arsenical dusts.

Some of the colonies were divided in order to convert their supers into brood chambers to indicate whether any disease might be present in the super combs. Only colony 17 developed any evidence of foulbrood after eight of such divisions were made and fed sulfa-sirup.

DISCUSSION.—Colony 6 (Table 1) was discovered on July 28, 1945, to be infected to the extent of 50 per cent with American foulbrood in all brood frames. It was reduced at that time to a single story, 5 infected combs of brood being retained. Feeding started on July 28, the sirup be-

ing poured directly into the combs on the first feeding. It was then fed two additional gallons of sulfa-sirup by a gravity feeder placed directly over the brood combs. No disease was observed after September 26, in 1945. However, on the second inspection in the spring of 1946, 13 cells of foulbrood were found in three combs. Two gallons of sirup containing 2 grams of sodium sulfathiazole were then fed over a period of 3 weeks and by June 1 no disease could be found. However, on on May 13, 1946, and was given the original queen. On May 15, a comb containing 292 foulbrood scales on one side and 361 cells with scales on the opposite side was placed in the center of its brood chamber. The side of the comb containing 292 scales of foulbrood was filled with sugar sirup containing 0.5 gram of sodium sulfathiazole to the gallon while the other side was left empty. The colony was also fed sulfa-sirup in a gravity feeder placed over the brood combs. Three days later the scales had been removed entirely from the side that had been filled and partially removed from the other side of the comb. The colony was fed a total of 1.75 grams of sodium sulfathiazole over a period of 3 weeks. Healthy brood was reared in the comb that formerly contained the 653 scales of foulbrood and no disease developed in the colony. This case indicated that the sulfa-sirup apparently softened up the scales in the cells in which the sirup had been poured and that the bees removed the scales and used the sulfa-sirup without contaminating healthy larvae. The total amounts of sulfathiaozle noted in table 1 may have been in excess of the amounts probably required in some instances but were purposely so fed to determine if any detrimental results would

Table 1.—Summary of records of colonies at Davis and Winters, California, treated with sodium sulfathiazole for the control of American foulbrood.

No. of Colony	First Date of Treatment	Amount of Infection	Last Date Foulbrood Observed	Amount of Sulfa Fed (gms.)	Period of Feeding
1	5-16-45	2 cells	5-27-45	8.70	3 weeks
2	5-18-45	60 cells	6-30-45	4.80	6 weeks
3	5-30-45	3 cells	7- 7-45	6.00	3 weeks
4	5-28-46	6 cells	6- 9-45	5.00	3 weeks
5[1]	—	0	—	0	—
6	7-28-45	50%	See discussion	5.75	See discussion
7[1]	5-13-46	1 cell	6- 1-46	2.00	3 weeks
8	9-18-45	5%	See discussion	3.25	See discussion
9[1]	—	0	—	0	—
10[1]	5-15-46	653 cells	5-28-46	1.75	3 weeks
11	3-26-46	1 cell	4- 4-46	1.75	6 weeks
12[1]	—	0	—	1.00	4 weeks
13	4-15-46	1 cell	4-23-46	2.00	6 weeks
14[1]	—	0	—	1.00	3 weeks
15	4-22-46	2 cells	5- 2-46	1.50	4 weeks
16[1]	—	0	—	1.25	3 weeks
17[1]	4-23-46	1 cell	5-13-46	1.50	4 weeks
18	5-25-46	25%	7-26-46	1.50	2 weeks
19[2]	6- 5-46	1 cell	7- 5-46	.25	2 weeks

[1] Signifies colonies that were made by dividing previously diseased colonies.
[2] This colony was only a 4-frame nucleus when fed sulfathiazole. It later was transferred to a regular hive and became a normally healthy colony.

August 6, 1946 two cells of foulbrood were discovered and on September 18, several more cells were found in 5 combs. One and one-half grams of sulfa were fed in sugar sirup over a period of 4 weeks and on the last examination, October 17, no disease was evident, and the colony was of normal strength in a two-story hive.

Colony 8 was divided twice to make three colonies after the initial infection had cleared up in a three-story colony. Three weeks after the divisions were made, one cell of foulbrood was found in the parent colony. One 5 pound tin of sugar sirup containing 0.25 gram of sodium sulfathiazole was fed to it and no further evidence of foulbrood has been observed.

Colony 10 was a division of Colony 8

occur. In the cases of colonies 1, 2, 3 and 4, no ill effect of the sulfathiaozle was noted on the brood or bees and no injury was noted when 1 gram (one-half teaspoonful) of sulfathiazole was fed in a 10-pound tin of sirup.

Several cooperating beekeepers reported that sulfa-sirup had little or no effect on eliminating European foulbrood and two beekeepers reported that the disease was worse in those colonies fed sulfa-sirup. The cooperators' reports on the efficiency of sulfa-sirup in treating foulbrood colonies were generally favorable. One cooperator reported favorable results when colonies with American foulbrood were fed sulfathiazole in soybean flour made into a paste with sugar sirup. The paste was placed directly over the brood frames whenever a lightly infected colony was found. Unfortunately he did not know the amount of sulfathiazole thus fed to each colony.

All the combs and hive bodies of the treated colonies that are being held over have been marked to indicate their origin and intended use and all such equipment will be kept separate from other colonies. Due to the occasional recurrence of foulbrood in sulfa-fed colonies, it will be essential to keep all such units separate from healthy colonies and equipment. Most of the commercial beekeepers in California prefer to destroy the occasional diseased colony rather than to quarantine and treat with sulfathiazole.

It seems obvious, however, that the use of sulfathiazole may have a definite place in the control of American foulbrood but its use will not result in a lessening of the need for efficient periodic inspection for foulbrood on the part of the beekeeper or of the inspection service. Haseman's suggestion of feeding sulfa-sirup to each colony in the spring or fall as a part of the regular apiary routine may have considerable merit in areas where foulbrood is known to occur, for at such times the colonies use the sirup in rearing brood. It might also be of advantage in feeding sulfa-sirup to swarms of unknown origin that are hived on drawn combs that might also contain some disease. However, the indiscriminate feeding of sulfathiazole in sugar sirup simply as a stimulant to the bees or as a "preventive" of disease is hardly justifiable and, conceivably, might result in injury to the honey industry if carried to excess.

The apparent disappearance of the disease might lead the careless observer to consider that the disease has been eliminated and result in spreading the infection if the combs are not kept strictly on the treated colonies. The sulfa treatment may also tend to encourage carelessness among those who have had insufficient experience with the disease to know that it is an extremely costly disease to harbor in a beekeeper's equipment. Our present results would indicate that the sulfa treatment of diseased colonies should be confined to quarantined apiaries and conducted under the supervision of qualified inspectors.

Weak and badly infected colonies should be destroyed since their recovery to a point of becoming productive would require 6 weeks or more and necessitate an uneconomic amount of food and care. Colonies that are strong in bees can be assisted in the treatment by destroying all badly infected combs and feeding the sulfathiazole in a dilute sugar sirup until the disease disappears. The sulfathiazole treatment may not fit in safely or economically with a migratory system of beekeeping.—12-12-46.

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The Sulfathiazole Cure of American Foulbrood: an Explanatory Theory[1]

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The demonstration of cure of American foulbrood with sulfonamide drugs has been confirmed by many individuals. A clear understanding of the factors involved seems essential in order to design means of effective application. However, no satisfactory explanation of the phenomenon has been presented. The purpose of this paper is to offer data and discussion contributing to an explanation.

Experiments.—A disease apiary was established in isolation with the approval of the Georgia State Entomologist. Banded Italian bees were used throughout. No bees selected for disease resistance and no golden Italians were used. No combs were removed from colonies except for momentary observation. Experiments on 17 colonies are reported here.

Exposure to American foulbrood was by either of two methods: (1) a shallow comb well filled with foulbrood scales (approximately 3000) was placed in the center of the brood nest, or, (2) brood of susceptible age was atomized with a suspension of *Bacillus larvae* spores. Both methods were effective in producing disease except where preventative treatments were started simultaneously with inoculation.

Treatments consisted of feeding the colonies sugar syrup or honey in which various drugs at various concentrations were dissolved or suspended. All treatments were administered at weekly intervals, and all drugs used were in true solution except sulfathiazole used in Series A and aspirin used throughout. Drugs and ingredients of treatments are indicated by Series Letter as follows:

Series A—0.5 gram of drug or no drug (as indicated by table 1) in 2 liters of sugar syrup (50–50 by volume).

Series B—0.5 gram sulfathiazole and a suspension of *Bacillus larvae* spores from two ground foulbrood scales in two liters of dilute honey (one part honey, three parts water).

Series C—1 gram aspirin suspended in two liters of dilute honey.

Series D—8 grams of sodium benzoate in four liters of dilute honey.

Series E—0.5 gram sulfathiazole in two liters sugar syrup.

Series F—1.5 grams sulfathiazole in four liters of dilute honey.

Series G—2 grams sodium sulfathiazole in four liters of dilute honey.

Table 1 presents data on the reactions of the bees to the inoculation combs and the effects of preventative treatments. Table 2 presents data on the treatment of diseased colonies with drugs.

From table 1 it may be observed that colonies treated with sulfathiazole, sodium sulfathiazole, and aspirin failed to contract American foulbrood. All other comb inoculations produced the disease promptly. Colony 8 developed a serious case of the disease. It may be further noted that all of the treated colonies of Series A, including colony 8, cleaned up and completely occupied the inoculation comb in 3 weeks regardless of medication. No differences in response were observed between sulfa treated colonies and controls treated with aspirin or syrup alone. Clean-up of inoculation comb occurred in all of the four untreated colonies observed, but was regarded as complete in 3 weeks in only one case.

Treatments with aspirin and sodium benzoate (table 2) were ineffective in curing foulbrood. But colony 26 (table 1, aspirin) failed to contract the disease and colony 21 (table 2, sodium benzoate) cleaned up the disease after the infection was established. Neither of these colonies received sulfathiazole. These two observations, plus the high efficiency of clean-up observed in Series A, seem to indicate that clean-up activity is stimulated by syrup feeding rather than drugs. None of the observations indicate stimulation of clean-up by drugs.

Table 2 records the experimental conditions under which nine colonies were "cured" of foulbrood with sulfathiazole in various feeding mixtures and one was "cured" with sodium benzoate in diluted honey. Colonies 35 and 37 were "cured" although during treatment each received *Bacillus larvae* spores from a total of 14 foulbrood scales in the sulfathiazole mixture. When sulfathiazole was added to

[1] Paper presented on the Richmond Program, Dec. 1946.
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Table 1.—Results of American foulbrood comb inoculations with and without preventative treatment, June 20–July 20, 1946.

Series	Colony No.	Treatment at Time of Inoculation	Duration of Treatment	Inoculation Comb after 3 Weeks		American Foulbrood in Colony	
				Condition	Use	4 Weeks after Inoculation	Later Inspections
A	18	Sulfathiazole	4 weeks	Clean	Brood and honey	0	0
	17	Sodium sulfathiazole	4 weeks	Clean	Brood and honey	0	0
	26	Aspirin	4 weeks	Clean	Brood and honey	0	0
	8	Syrup only (control)	4 weeks	Clean	Brood and honey	18 cells	+
B	35	None		24 scales	Honey only	100 cells[1]	+
	37	None		(Not observed)		300 cells	+
C	36	None		Clean	Brood and honey	135 cells[1]	+
	38	None		(Less than half the scales removed)		123 cells	+
F	39	None		Half clean	Honey only	1000 cells[1]	+

[1] Datum estimated.

contaminated honey, the honey became not only harmless, but curative. Colonies J2 and J3 were cured with their own honey. Sealed honey combs from the supers were scraped to the midrib on one side only, and the honey was mixed with a sulfathiazole-water solution for feeding. The combs were quickly rebuilt by the bees and the opposite sides were scraped the next week. Although this method can spread disease it achieves two purposes, (1) sugar or honey is not wasted on colonies which don't need it, and (2) contaminated stores of honey which could be a source of reinfection are removed. Extraction, medication, and refeeding of honey would be more satisfactory.

Three colonies showed recurrence of the disease at 1 to 2 months after the end of sulfathiazole treatment. Colony 33 showed evidence of queen failure and was requeened after 7 weeks of treatment. All three of these colonies were natural infections of long standing in serious condition, and with 25 to 40 pounds of honey on hand at the time of treatment. Feeders were usually empty at the time of the next weekly treatment. Apparently, these colonies retained sufficient infection in the stores to reproduce the disease after the medicated syrups were exhausted or ceased to be effectively consumed.

DISCUSSION.—The activity of bees in removing brood dead of foulbrood from the comb was recognized by Richmond (1936), and Park (1936) as a logical basis for disease resistance. Although Park focused attention on the selection of bees which were sufficiently active to free themselves of the disease, the removal of dead brood from inoculation combs by "non-resistant" colonies was also recorded. Woodrow (1941) and Woodrow & States (1943) established that the removal of dead brood from the comb was a general phenomenon of disease resistant and disease susceptible bees alike. By detailed observations of the behavior of bees toward individual cells containing dead brood these authors conclude: "Since the bees of all 32 colonies studied, representing 16 strains of three races, removed diseased brood from the cells, it is likely that this is a common behavior characteristic of honeybees."

The clean-up activities recorded in the untreated colonies of table 1 find explanation in the findings of Woodrow & States. However, the increased efficiency of the clean-up in the case of all colonies of Series A is not explained. The stimulation of syrup feeding is believed to account for this result. Casual observations of the writer while he was an apiary inspector in a western state bear on this question. American foulbrood was rampant in certain areas, and area clean-up by burning was not practiced consistently. Colonies which developed foulbrood infections just prior to the main honey flow were fre-

Table 2.—Results of treating American foulbrood colonies with drugs July 20-November 20, 1946.

Series	Colony No.	Drug	Duration of Treatment	American Foulbrood Observed in Colony			
				At 1st. treatment	1 wk. after last treatment	1 mo. after last treatment	2 mo. after treatment
B	35	Sulfathiazole +Foulbrood	7 weeks	100 cells[1]	0	0	0
	37	Sulfathiazole +Foulbrood	7 weeks	300 cells[1]	0	0	0
C	36	Aspirin	7 weeks	135 cells	1000[1]	+	
	38	Aspirin	7 weeks	123 cells	10–20 cells per comb	+	
D	11[3]	Sodium benzoate	10 weeks	50–100 cells[1]	200 cells	+	
	21[3]	Sodium benzoate	7 weeks	50–100 cells[1]	0	0	0
	8	Sodium benzoate	10 weeks	18 cells	1000 cells[1]	+	
E	31[2]	Sulfathiazole	7 weeks	1000's no healthy brood	0	10 cells (treatment resumed)	
	J1[2]	Sulfathiazole	7 weeks	50 cells	0	0	0
F	33[2]	Sulfathiazole	12 weeks	1000's healthy brood	0	12 cells (some treatment resumed)	
	39	Sulfathiazole	7 weeks	1000 cells[1]	0	0	0
	J2[2]	Sulfathiazole	3 weeks	18 cells	0	0	0
	J3[2]	Sulfathiazole	3 weeks	24 cells	0	0	0
G	34[2]	Sodium sulfathiazole	7 weeks	1000's cells[1]	0	0	7 cells

[1] Datum estimated.
[2] Natural infection.
[3] Spray inoculation.

quently run from the crop and salvaged afterward. A considerable number of these small late infections would show no signs of disease after the honeyflow. The inspector was consulted at least five times on what to do with these colonies that had cleaned up. "Shake your foul on the dandelion flow" was a common saying among commercial operators. Whether by dilution of inoculum or by stimulation of disease-resistant activity or both, the honeyflow seemed to have a definite relationship to the process whereby the colony freed itself of disease. The artificial honey flow created by syrup feeding is commonly used to stimulate brood rearing and comb building; and it has certain advantages over the natural flow, it is continuous night and day, and it is not subject to the weather.

Two phenomena are requisite to the disappearance of visual evidence of an established foulbrood infection, (1) the removal of dead brood, and (2) the cessation of brood mortality due to the disease. The former is well established. The reason the infected colony dies out is that two or more larvae become infected while one cell is being cleaned. Cessation of brood mortality due to the disease is achieved in disease resistant bees by removing the inoculum (dead brood). Any drug with bacteriostatic or disinfectant powers over *Bacillus larvae* can achieve the same result. In fact, this is all that is required to break the cycle in the presence of active disease. If the demonstration is valid that non-medicated bees remove brood as effectively as sulfa-treated bees the remaining explanation is that sulfathiazone has the same bacteriostatic powers toward *B. larvae* that it is known to have toward

other pathogens. Any *in vitro* results are of questionable implication. MacLeod (1940) demonstrated the inhibition of bacteriostatic action of the sulfonamides by certain substances of animal and bacterial origin; namely, seven peptones including bacto-neopeptone, three casein hydrolysates and various animal tissues and fluids. In the sulfathiazole treatment, the brood mortality due to disease stops and the bees gradually clean out existing dead brood. The need for a bacteriostatic or bactericidal agent is satisfied.

For a permanent cure of American foulbrood there is a third requisite, any inoculum within the hive must be removed or consumed while the drug is still effective. Continuous feeding not only gives the colony a respite in which to clean up, it also permits the colony to store medicated syrup in proximity to infective honey and thus lengthen the period of medication. But treatment by feeding is somewhat paradoxical. Medicated syrup is fed with the hope that the bees will consume their own infective honey before the syrup gives out. When the supply of medicated syrup is exhausted first, the disease reappears. It is not strange to find disease-resistant bees used to hasten the clean-up. and combs removed to shorten the required medication period.

SUMMARY.—Bee colonies fed sugar syrups with and without drugs were observed to remove dead brood from foulbrood combs more effectively than unfed colonies. No increase in efficiency of clean-up was evidenced by drug treatments.

One colony treated with aspirin in sugar syrup failed to contract American foulbrood and one colony treated with dilute honey plus 0.2 per cent sodium benzoate cleaned up the disease. Aspirin treatment failed to cure two colonies and sodium benzoate failed to cure two colonies.

Two colonies were cured with sulfathiazole syrup contaminated with foulbrood spores. Nine colonies were cured of American foulbrood with sulfathiazole and sodium sulfathiazole treatments. Of this number three badly diseased colonies showed recurrence within 1 to 2 months.

CONCLUSIONS.—Sulfathiazole appears to have bacteriostatic or bactericidal action on *Bacillus larvae* by the cessation of brood mortality in the presence of an adequate inoculum of the pathogen. A drug having such properties is all that is required to achieve a temporary cure because the bees normally remove dead brood. Clean-up activity is apparently increased by the stimulation of a natural or artificial honeyflow rather than by drugs. Permanent cure of American foulbrood with drugs requires that infective material within the hive be removed or consumed while the drug is effective in preventing brood mortality.—12-12-46.

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Mr. Raymond Roberts resigned from his position in the Texas Agricultural Experiment Station on January 31, 1947, to accept the position of Entomological Adviser to the Military Government of Japan and left soon after that date to proceed to Japan. He is doubtless established in his new duties by this time.

Experiments with Insecticides on Honeybees[1]

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Since the discovery of DDT, the number of new insecticides appearing on the market has increased tremendously. This has naturally caused some anxiety to bee keepers, many of whom have inquired from time to time as to the toxicity of this or that new compound to honey bees. Most of the compounds were so recent that the literature contained no references as to their toxicity to bees, and it was these inquiries that prompted the laboratory tests described here.

It must be pointed out that not all compounds shown to be toxic in the laboratory are necessarily dangerous to bees when used in the field, since DDT is very toxic in cages but, under certain conditions at least, can be used quite safely on bloom frequented by bees. Compounds that show no toxicity at all, on the other hand, would not be very likely to cause more damage in the field, and so a few can be safely recommended without much further testing.

METHODS.—Cages were constructed of 18 mesh screen of a cylindrical shape and about 3 by 1.5 inches. The top was of screen and the bottom closed with a large cork. Five bees were used in each, and each test lot consisted of 4 cages. Each material was usually tested in three ways: (1) By contact, in which a small amount was applied to a heavy paper card 50 sq. cm. in area and inserted in the cage in such a manner that the bees would walk on it but would not have to ingest it. The cards used covered about 60 per cent of the inside surface of the cage, leaving the top for feeding honey and an open space in front through which to make observations. (2) By mixing with honey and water and allowing bees to feed on it through the cage. Mixtures were usually about 1 to 800 or approximately the strength used in sprays. If bees fed readily, which was usually the case, they were given pure honey after two feedings. If not, they were kept on the poisoned diet for a longer period but not over 2 days, in order not to complicate the data by starving them to death. (3) By spraying or dusting the caged bees, depending on which form was most convenient. After a few trials an arbitrary amount was selected and used for each material. This was 1 gram of each dust 2 feet away from the bees in a closed room or 4 cc. of a spray at the same distance. A small hand duster was used for the dry material and a hand atomizer for the sprays. In most cases the sprays were not too successful, although this amount was sufficient to cause small droplets to collect on the hairs of the bees. Evidently they were able to remove these by fanning with the wings or by some other method whereby they did not ingest the poisoned water or allow any of it to come in contact with sensory organs.

Bees were introduced into the test cages from a large holding cage made from a cage used to ship package bees. With the holding cage darkened by pieces of cardboard, the bees would file into the small cages usually in a very orderly manner through a small opening equipped with a sliding door. If irritated when being placed in the large cage, however, they sometimes refused to cooperate and would not leave. Forcing them with smoke often resulted in ruined tests due to the bees stinging each other, so that it was usually better to liberate them and get another cage full from a different hive.

All bees were fed honey three or four times a day by dabbing a small amount of it on top of the cages.

Check cages were started with each group of tests. Usually if more than 10 per cent died in the checks in 24 hours the tests would be repeated. Most of the checks, however, showed little mortality.

The list of materials tested includes cryolite and calcium arsenate, which are known to cause serious losses to bee keepers, also rotenone and DDT by way of comparison with materials about which nothing is known.

The materials are listed in table 1, with the average percentage mortality for 72 hours shown for each test.

DISCUSSION.—The first in table 1, 2,4 dichloro-phenoxyacetic acid, is not an insecticide but a hormone weed killer. Hormone sprays of this type are selective weed killers and usually work very slowly, so that plants sprayed with them could

[1] Paper presented on the Richmond Program, Dec. 1946.

Table 1.

Material	Date	Type of Test and Dosage	Per Cent Mortality after 24 hrs.	48 hrs.	72 hrs.
2,4 Dichloro-phenoxy acetic acid (*Weedon, Endoweek*, etc.) Hormone weed killer	8–22	1–500, 1 cc.–50 sq. cm. dried on card (Mortality same as check)	15	35	65
	8/22	50 ppm in 10% sugar solution (Mortality same as check)	5	80	90
	8/26	1 to 500 soaked and dried on card 0.001 gr./sq. cm. (Usual dosage for weeds)	0	0	0
	8/26	500 ppm in 10% Honey solution	0	0	0
Synthetic cryolite (Sodium aluminum fluoride)	8/24	Sprayed on surface	75	75	—
	8/26	Sprayed on surface	0	40	60
	9/23	0.002 gr./sq. cm. on 50 sq. cm. surface	100	—	—
	9/24	0.002 gr./sq. cm. ((All sick at 72 hrs.)	10	25	65
	9/23	1 to 800 fed in 50% honey water (All sick at 72 hrs.)	65	75	85
	9/23	1 to 400 spray (All sick at 72 hrs.)	5	15	25
Calcium Arsenate	10/ 1	.001 gr./sq. cm.	100	—	—
	10/ 1	1 to 800, fed with 50% honey & water	100	—	—
	10/ 1	1 to 400 spray 4 cc.—2 ft.	0	0	0
	10/ 1	10% dust—1 gr.—2 ft.	85	100	—
DDT—Dichloro-diphenyl trichloroethane	8/24	50% wettable—1 to 400 on paper card	100	—	—
	8/26	5% dust, 1 gr. 4 ft. distant	5	15	15
	8/29	0.025% DDT in 50% honey & water—2.5% acetone fed at top of cage (Fed readily—bees caged 3 days)	65	80	—
		Same material (New bees, not inclined to feed at first)	0	100	—
		5% dust, 1 gr. 2 ft. distant	90	95	—
	9/ 4	Acetone solution on 50 sq. cm. paper surface			
		0.1 gr.—.002 gr./sq. cm.	100		
		0.05 gr.—.001 gr./sq. cm.	100		
		0.02 gr.—.0004 gr./sq. cm.	100		
	9/ 6	Repetition of above, same cards used			
		0.002 gr./sq. cm.	100		
		0.001 gr./sq. cm.	100		
		0.0004 gr./sq. cm.	100		
	9/26	50% wettable powder 1 to 800 in 50% honey & water, fed (.0625%)	30	100	
	9/27	50% wettable powder 1 to 400—.01 gr. DDT on 50 sq. cm. surface	100		
	9/26	50% wettable powder 1 to 400 spray, 4 cc.—2 ft.	20	35	50
Piperonyl cyclohexanone 6.92%—pyrethrum extract—pyrethrins 0.69%. Dust piperonyl cyclohexanol 5%. Pyrethrins .004%	9/ 6	Extract 1 to 600, 1 cc. on 50 sq. cm. (.0023 mg./sq. cm.) PCH. (Dried 12 hrs. before exposure)	0	0	0
		1 gr. dust, 2 ft. away (Bees highly irritated but none killed.)	0	0	0
		Extract 1 to 1200 with 50% honey & water (Bees repelled)	0	20	20
	9/ 9	1 gr. dust 1 ft. away (Bees dusted white—all down in 30 min. but recovered)	15	15	15
		Extract 1 to 400 (0.25%) sprayed—4 cc.—2 ft.	0	0	0
	9/11	Extract 1 to 10 in. acetone—0.138 mg./sq. cm.	15	15	15

Table 1.—(*Continued*)

MATERIAL	DATE	TYPE OF TEST AND DOSAGE	PER CENT MORTALITY AFTER		
			24 hrs.	48 hrs.	72 hrs.
2,4 Dinitro-o-cyclo hexyl-phenol *DN-111* 20%	9/ 6	1 to 800 in 50% honey & water, fed (Fed readily)	80	95	100
	9/ 6	1 to 400 suspension in water, approx. 0.005 gr./sq. cm. (Bees noticeably affected but did not die)	0	5	5
	9/ 7	10% solution in acetone—0.004 gr. actual DN per sq. cm. (Bees all sick)	50	60	60
	9/ 9	1 to 400 spray—4 cc., 2 ft. (Bees affected)	0	0	0
	9/ 7	1 to 1600—75% honey & water (Bees all sick)	45	45	50
	9/12	Same as above (Bees all sick)	35	35	35
		0.0004 gr./sq. cm. 5 days on card	100	—	—
	9/13	Same as above, 6 days on card	80	100	
	9/23	Same as above, 16 days (All bees sick)	40	40	60
Rotenone	9/ 9	0.75% dust—1 gr., 2 ft.	0	0	0
	9/ 9	Extract—2.5% rotenone—1 to 400, 4 cc./2 ft.	0	0	0
	9/ 9	Ground derris 3.6—4% rotenone—1 gr./2 ft., dusted	5	45	45
	9/11	Extract—1 to 10 in acetone—1 cc. on 50 sq. cm. dried	0	10	15
	9/12	Extract—1 to 800 with 50% honey & water (Fed readily)	25	30	30
	9/12	Ground derris root—1.5 lbs. to 100 gal. (All fed readily)	30	45	55
Sabadilla	9/13	20% dust—1 gr. 2 ft. (Many down in 20 min. 85% dead in 3 hrs.)	100		
	9/13	3 of cages used above, new bees	100		
	9/15	20% dust—0.1 gr., 2 ft.	75	80	100
	9/15	20% dust—0.1 gr. on 50 sq. cm. surface, dried 42 hrs. (All dead, 3 hrs.)	100		
	9/23	Same surfaces, aged 9 days			100
Hexa-ethyl tetraphosphate	9/13	6% dust—1 gr., 2 ft. (80% dead, 3 hrs.)	100		
	9/13	2 of above cages	100		
	9/13	6% dust—0.1 gr., 2 ft.	50	70	
	9/15	0.1 gr. on 50 sq. cm. surface 100 dried 18 hrs. (All dead, 3 hrs.)	100		
	9/15	1 to 1600 in water spray, 4 cc., 2 ft.	95	100	
	9/23	0.1 gr. on 50 sq. cm. aged 9 days	0	10	20
Xanthone dibenzyl pyrone, 95%	9/24	1 to 800 fed in 50% honey water (Slightly repelled but all ate eventually)	0	0	0
	9/24	1 to 400 spray 4 cc. 2 ft.	0	0	0
	9/26	0.05 gr. on 50 sq. cm.	0	0	
	9/26	1 to 20 spray—4 cc., 2 ft.	0	0	0
	9/26	1 to 400 fed in 50% honey water (No more repellant than at 1 to 800)	0	0	0

Table 1.—(*Continued*)

Material	Date	Type of Test and Dosage	Per Cent Mortality after		
			24 hrs.	48 hrs.	72 hrs.
Dianisyl trichloro-ethane or Dimethoxy trichloro-ethane (Orthotox-Cal. Spray Chem. Co.) 25% wettable powder	9/24	1 to 800 in 50% honey & water (All fed readily)	0	0	0
	9/24	1 to 400 spray	0	0	0
	9/26	.05 gr./50 sq. cm. surface	100		
	9/26	.1 to 200 spray	0	0	0
	9/26	1 to 400 fed in honey & water (Fed readily)	5	80	85
	9/27	.02 gr./50 sq. cm. surface	100		
Velsicol 1068—20% solution	9/30	.1 gr. 50 sq. cm.	0	0	0
	9/30	1 to 400 spray—4 cc., 2 ft.	0	0	0
	9/30	1 to 800 fed in 50% honey & water (All fed but not readily)	0	0	0
Phenothiazine (Thiodiphenyl-amine) Micronized powder	10/ 1	.1 gr. on 50 sq. cm. surface	0	0	15
	10/ 1	1 to 800 fed in 50% honey & water	0	10	10
Checks	8/22	No treatment	25	25	35
	8/23	No treatment	5	65	95
	8/24	No treatment	0	90	
	8/26	No treatment	0	0	0
	8/29	No treatment	0	0	0
	9/ 4	No treatment	0	0	5
	9/ 9	No treatment	0	0	0
	9/12	No treatment	5	5	5
	9/13	No treatment	0	0	0
	9/15	No treatment	5	5	20
	9/23	No treatment	0	0	0
	9/24	No treatment	0	5	5
	9/26	No treatment	0	0	0
	9/30	No treatment	0	15	20
	10/ 1	No treatment	0	0	15

be visited by bees for days before the plants died. The tests, however, indicate no toxicity to bees. There is a possibility that bees might carry the material from weeds to cultivated crops, since very small amounts are known to cause symptoms in some plants, but this would be of little concern to bee keepers. Sodium chlorate and weed killers containing arsenic would doubtless be toxic to bees, but kill the plants so quickly that there would be little occasion for bees to visit blossoms sprayed with them.

Cryolite (synthetic) and calcium arsenate were both highly toxic, the latter a little more so, except that the spray did not seem to work. This is in accord with experience in the field.

In these tests DDT proved toxic in all cases, and highly toxic in most. Eckert[1] in California also found it toxic but claimed that as a dust it was only slightly so, and fed in pollen not at all. Observations during the season in the lower Yakima Valley indicate that the 5 per cent dust as applied to potatoes is a great deal less toxic than the cryolite and arsenical dusts previously used.

Piperonyl cyclohexanone, a derivative of the pepper plant, is commonly used with a small amount of pyrethrum. It is used as a contact insecticide the same as rotenone, although a few workers claim it has great residual toxicity against some insects. Out of six tests, it killed bees in only three, and then only low percentages. Dusted heavily, bees were knocked out for an hour or so but recoverery was almost complete. Fed with honey, it was highly repellent. Everything considered, this is one the bee keepers should not have to worry about.

Since the advent of DDT, the dinitro compounds have come into prominence in apple growing districts as a material for controlling mites. The compound used in

[1] Jour. Econ. Ent., 38: 3; June, 1945.

these tests, 2,4 dinitro-o-cyclohexylphenol, is the active constituent of a spray known as *DN-111* and a dust known as *DN-4*. In these tests it proved toxic in all cases except as a spray, which form, as noted before, was usually not as effective as the other tests. When bees were fed or allowed to crawl over a surface covered with it, it was highly toxic, although not as toxic as DDT. The toxic action was slow and the affected bees were lethargic and refused to eat, remaining in that condition sometimes for days. The *DN-4* dust was used extensively for mites on hops during the past season but no cases of bee poisoning were reported. Another DN compound, dinitro-o-cresol, is sometimes used for chemical thinning of apples. According to Goble & Patton[1] of Cornell University this compound is about twice as active physiologically as the phenol derivative, and both are highly toxic to honey bees. No damage to bees or brood has been reported yet, but the compounds are a potential threat and bee keepers would do well to keep this in mind when they place bees in orchards for pollenization purposes.

Rotenone was included in this series for comparison. It is usually regarded as the least toxic of insecticides as far as bees are concerned. In these tests it had no effect as a 0.75 per cent dust or as a spray, but a 3.5 to 4 per cent dust killed 50 per cent and it was also toxic as a stomach poison. It was definitely more toxic than piperonyl cyclohexanone, xanthone, phenothiazine, or *Velsicol 1068*.

Sabadilla, an organic compound extracted from a liliaceous Mexican plant, is used extensively to control the squash bug since some varieties of squash are injured by applications of DDT. It comes in dust form at 10 and 20 per cent strengths. The 20 per cent dust used here was among the most toxic materials tested. It killed all of the bees by every method tried and had a residual toxicity lasting over 9 days. Two hives of bees placed in a squash field were not injured noticeably, but it was afterwards discovered that the grower had dusted only in scattered spots, which did not give a real test.

Hexaethyl tetraphosphate is a new contact insecticide of German origin introduced as a substitute for nicotine. The manufacturers claim that it is dissipated even faster than nicotine, but a residue of it dried on a surface for 18 hours was 100 per cent toxic to bees. After 9 days the same surfaces were still slightly toxic. It was highly toxic in both spray and dust form.

Xanthone (dibenzyl pyrone) was very promising as a substitute for lead arsenate up to the advent of DDT. It is still being promoted by one company as an adjunct to DDT to control mites. It was entirely non-toxic to bees in these tests. Not one bee was killed. They were slightly repelled but could be starved into eating it.

Dianisyl-trichloroethane, also called dimethoxy-trichloroethane, is one of the numerous analogs of DDT. It is being used experimentally by California Spray Chemical Company as *Ortho-tox*. Against bees, the results are rather inconsistent, as they often are with DDT. When used as a spray, or when fed with honey, it showed only slight toxicity, but when bees were allowed to crawl over a treated surface it proved highly toxic. Apparently the action is similar to DDT but to a less degree, and it could be expected to be safe to bees under the same conditions that DDT is safe.

Velsicol 1068,[2] a new chlorinated hydrocarbon, was reported[3] (Kearns, *et al.* 1945) to be more toxic to insects than DDT. In these tests it did not kill a single bee. The sample used, however, was only 20 per cent strength and certainly was not colorless or odorless as was the compound described by the above authors.

Phenothiazine (thiodiphenylamine), another promising substitute for lead arsenate a few years ago, is included here because it has shown good results against the cherry fruit fly and might come into general use. In two tests it showed slight toxicity to bees, but in the light of work done by others should be regarded as practically non-toxic to bees.

Benzene hexachloride (hexachlorocyclohexane) was not tried in the laboratory but was used to exterminate a colony of bees in the walls of a house. It proved highly toxic, killing the colony completely in a few hours.

FIELD OBSERVATIONS.—Of the above

[1] JOUR. ECON. ENT., 38: 2, April, 1946.

[2] Made by the Velsicol Corp., Chicago, Ill. Sample furnished by California Spray Chemical Corp.

[3] JOUR. ECON. ENT., 38 (6): 661.

materials, field observations were made on only one, DDT. In spite of the fact that this compound was demonstrated to be toxic to bees in cages, the observations made indicated strongly that when applied to potatoes a 5 per cent dust at the rate of 35 to 50 pounds per acre it was either non-toxic to bees, or so much less toxic than cryolite or calcium arsenate as to appear non-toxic. The following cases are offered as proof.

A potato grower near Toppenish, Washington, had kept bees for years. In 1945 he had seven stands, which just about furnished his family with honey. An examination of this dismal apiary revealed numerous "crawlers" or sick bees each morning, and an analysis proved that these were poisoned with calcium arsenate, which he had applied to his own potatoes in nearby fields. In 1946 he used 5 per cent DDT instead. The bees increased in numbers tremendously; by July he had 12 healthy stands and at least four large swarms got away. Honey production was far greater than he had ever known before.

One of the larger honey producers in Union Gap, Washington, very kindly left one healthy stand of bees near an isolated 100-acre potato field south of White Swan, Washington. The field had been in alfalfa in 1945, and a good stand came up the following year in the potato rows. As far as known, there were no other honey plants of importance within two miles. The field was dusted by plane on June 24 using 3500 pounds of 5 per cent DDT; on July 7, using 5750 pounds of the same; and on August 10 using 5150 pounds. The hive was located at the edge of the field but could not have been avoided in the dusting operations. It was examined on June 29, July 17, and August 10. On each occasion it had two full supers of honey, the bees seemed in good condition and were very cross, usually an indication of good health. There were no dead bees to be found in the colony.

Another bee keeper, one mile west of White Swan, had threatened to sue a neighbor who raised potatoes if his potato dust killed any of the bees. The potato grower took a chance and dusted twice by plane during June, using 5 per cent DDT. The dust cloud passed within a few hundred yards of the bee yard, but no bees died. The bee keeper, who had had experience with poisoning in previous years, said the bees must have flown the other way on the days the dust was applied, which was very unlikely.

The manager of a winery near Sunnyside, Washington, claimed that bees were left in the vineyards while they were dusted with DDT for grape leafhopper with no apparent effects.

While these incidents do not prove that DDT is not toxic to bees in the field, they add to the growing weight of opinion that it is far less toxic than the insecticides formerly used.

On the other hand, a fairly strong colony of bees was left in an isolated orchard near Tieton, Washington, early in July. This orchard had been sprayed three times with 0.75 to 1 per cent DDT previously, and once after the hive was left there. No dead bees or "crawlers" were ever found, and the colony did not seem to dwindle in numbers, but they did not store more than a few cells of honey and did not draw any comb during the summer and fall, although there was ample pasture of sweet clover and alfalfa in the cover crop. However, *DN-111* which has been shown to be toxic also was used in every spray. At present it is not considered advisable for bee keepers to take advantage of the bee pasture in DDT-sprayed orchards until more observations can be made.

CONCLUSIONS.—(1) Of the materials tested, 2,4 D, piperonyl cyclohexanone, *xanthone*, *Velsicol 1068*, and phenothiazine are non-toxic to bees.

(2) Rotenone and dianisyl trichloroethane are toxic under certain conditions.

(3) Cryolite, calcium arsenate, dinitro compounds, DDT, sabadilla, hexaethyl tetraphosphate, and benzene hexachloride are highly toxic.

(4) Bee keepers are advised to be on the lookout for orchardists using dinitro compounds for blossom thinning.

(5) Field observations indicate that DDT is much less toxic to bees than calcium arsenate or cryolite when used as a 5 per cent dust. 12-12-46.

Controlled Crystallization of Honey[1]

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In an effort to simplify, not replace, the Dyce process[2] of making finely crystallized honey and avoid the trouble caused by an occasional batch of honey starter that is not smooth enough for this purpose, several types of powdered sugar were tested as starter or seed. The first sugars tested were commercial powdered sugar and finely powdered white granulated sugar. The latter was powdered in the laboratory with a mortar and pestle.

Each of these sugars was mixed with liquid honey and placed in the refrigerator at 57° F. Concentrations of 1 per cent and 2 per cent of each type of powdered sugar were used. A check composed of the same liquid honey and 10 per cent finely crystallized honey was added for comparison. All samples were examined on the third day and found to be liquid or nearly so. The check batch containing finely crystallized honey was found to be crystallized solidly on the second examination or the fifth day, while the honey containing the two forms of powdered cane sugar or sucrose remained liquid. Periodical observations were made for a total of 3 weeks following this date, when the two samples containing powdered sugar were still apparently unchanged and in the liquid form. The temperature of the refrigerator remained at 57° F. for the 2 weeks and 5 days. This length of time was considered excessive for commercial crystallization, and powdered sucrose was recorded as unsatisfactory.

A second attempt was made to solve the problem by using powdered dextrose. The crystals of the commercial powdered dextrose purchased were found to be too coarse to use as seed, so a small batch was ground with a mortar and pestle as was the cane sugar. The powder obtained was quite fine and appeared satisfactory even though considerable effort had to be expended to obtain the desired fineness.

The same quantities of powdered dextrose were used, namely 1 and 2 per cent. The powder was mixed thoroughly with the liquid honey and then bottled. It was observed that many lumps of powdered dextrose failed to break up while the honey was stirred.

The seeded honey was placed in the refrigerator at 57° F. At the end of 5 days both samples were checked and found to be crystallized solidly. Upon examination, the samples seemed to be somewhat softer and smoother than the check sample in which finely crystallized honey was used as seed.

These results offered enough encouragement to stimulate the preparation of a larger set of trials for powdered dextrose. The honey used in this series had been heated to 160° F. and cooled to room temperature before the dextrose was added. The following figures give the details of the second series of tests:

Sample No.	Powdered Dextrose and Liquid Honey
1	2 per cent
2	1 per cent
3	0.5 per cent
4	0.25 per cent
5	10 per cent

All samples were placed in the refrigerator at 57° F. on September 17, 1945, and the results obtained are shown in table 1.

A sample of honey seeded with 5 per cent crystallized honey and 0.5 per cent powdered dextrose was treated the same as the samples tabulated above. This sample, when crystallized, had a texture more solid than when only powdered dextrose was used, but was softer than when crystallized honey alone was used as seed. Another sample seeded with 10 per cent honey originally crystallized with 1 per cent powdered dextrose, crystallized with a somewhat softer texture than when normally crystallized honey was used.

A test was run to learn what effect the percentage of water has on the rate of crystallization. The honey used was gathered in late summer and may have contained a small per cent of honeydew. The refrigeration temperature was 57° F. The results of this test are given in table 2.

A final test was started November 11 in order to study the rate of crystallization for two types of honey, one a summer honey of mixed floral source and the other fall honey from goldenrod and wild aster. This batch was refrigerated at 54° F.

[1] Authorized for publication on March 24, 1946 as paper No. 1367 in the journal series of the Pennsylvania Agricultural Experiment Station.

[2] Patented by Cornell University.

Table 1.—Tests of powdered dextrose in crystallization of honey.

DATE	PER CENT POWDERED DEXTROSE ADDED AND SAMPLE NO.				
9/17/45	No. 1 2%	No. 2 1%	No. 3 0.5%	No. 4 0.25%	No. 5 10%
9/21/45	Crystallized solidly	Crystallized solidly	Crystallized soft	Very thick	Crystallized solidly
9/23/45	Crystallized solidly	Crystallized solidly	Crystallized solidly	Crystallized soft	Crystallized solidly
9/24/45	Crystallized solidly	Crystallized solidly	Crystallized solidly	Crystallized solidly	Crystallized solidly
Condition of crystallized honey	Smooth soft texture	Smooth soft texture	Smooth soft texture	Trace of fine crystals	Solid texture, trace of fine crystals
10/1/45	All samples removed from refrigerator and stored at 80° F.				
Condition of honey at 80° F. 10/5/45	Smooth firm	Smooth firm	Smooth, holds shape but soft	Holds shape temporarily	Solid hard texture

for the first 4 days because of thermostat trouble, then at 57° F. from November 16 on. The lower temperature undoubtedly retarded crystallization some until November 16. The results are given in table 3.

Difficulty was encountered at first in powdering commercial dextrose crystals. The first powder ground with a mortar and pestle required excessive time and energy. A second batch was ground in a flour mill which was also found to be unsatisfactory since the powdered dextrose caked on the discs and refused to flow through freely. A ball mill was then prepared, using two rollers from a washing machine, a set of reduction pullies, and a small motor. The dextrose was placed in a gallon friction top can with 5 pounds of quartz pebbles. This mill did an excellent job and produced a fine powder. The speed of the motor was reduced by using a 1.5 inch pulley on the motor, and a 6 inch pulley on a shaft with a second 1.5 inch pulley between the motor and rollers, plus an 8 inch pulley on one roller. This combination gave the gallon bucket a speed of 34 revolutions per minute. Almost any degree of fineness can be obtained with this equipment. About 8 hours running were required for each batch of powder.

The second difficulty, that of getting

Table 2.—Effect of percentage of water on crystallization of honey.

DATE 11/20/46	0.75 PER CENT POWDERED DEXTROSE ADDED TO THICK HONEY[1]	0.75 PER CENT POWDERED DEXTROSE ADDED TO SAME HONEY+4% WATER
11/22/46	Liquid	Liquid
11/23/46	Liquid	Liquid
11/25/46	Flows slowly	Holds shape, soft
11/26/46	Nearly solid	Solid fine crystals
11/28/46	Holds shape, soft	Solid
11/29/46	Solid	Solid

[1] Both the flavor and the texture were more pleasing in the honey without water.

Table 3.—Comparison of summer honey with fall honey in crystallization tests.

DATE 11/11/46	POWDERED DEXTROSE 0.5 PER CENT		POWDERED DEXTROSE 0.25 PER CENT	
	Summer Honey	Fall Honey	Summer Honey	Fall Honey
11/12/46	Liquid	Liquid	Liquid	Liquid
11/15/46	Liquid	Liquid	Liquid	Liquid
11/16/46	Liquid	Liquid	Liquid	Liquid
11/18/46	Liquid	Holds shape, soft	Liquid	Liquid
11/20/46	Flows very slowly	Solid	Liquid	Holds shape, soft
11/21/46	Holds shape, soft	Solid	Flows slowly	Solid
11/23/46	About solid	Solid	Flows very slowly	Solid
11/25/46	Solid	Solid	Holds shape, soft	Solid
11/26/46	Solid	Solid	Solid	Solid

the lumps of powdered dextrose broken and mixed with the liquid honey, was solved by adding a small amount of liquid honey to the powdered dextrose and mixing the two thoroughly to form a thin paste. The paste was mixed until smooth, then added to the liquid honey in the tank, when no further trouble was encountered. A special type of mixer can undoubtedly be developed for this purpose where large quantities are needed.

The question of adulteration naturally arises when anything is added to a food product. It seems quite doubtful that the addition of dextrose to honey can be considered adulteration, since the honey itself contains about 34 per cent dextrose. Hence nothing is added not already found in honey or which will lower its food value. It is quite probable, however, that the added dextrose will have to be declared on the label.

SUMMARY.—The results of this study indicate that powdered dextrose may be used as seed to crystallize liquid honey in percentages as low as 0.25 per cent. The crystallized honey obtained has a softer texture than when honey is used to stimulate fine crystallization. By using either powdered dextrose or honey or a combination of the two, almost any desired degree of hardness may be obtained. It was also found that thin honey crystallizes more rapidly than thick honey, and that the floral source has a bearing upon the rate of crystallization.—12-12-46.

The Cabbage Maggot in Northwest Washington[1]

ELMER C. CARLSON, E. P. BREAKEY, and R. L. WEBSTER[2]

Most of the cabbage seed produced in the United States is raised in western Washington. Although cabbage seed may be produced in other western Washington districts, the center of the industry is in Skagit County, between Mount Vernon and LaConner and south of Skagit Bay. In the Skagit area, which includes portions of adjoining counties, the cabbage acreage has varied from a low of about 550 acres to about 2500 acres a season in the past 4 years.

The yield of seed per acre of cabbage had fallen from a former average of 800 pounds to 402 pounds in 1942, due principally to losses from insect pests and diseases. The low yield cited is close to the previous 10-year average of only 380 pounds. These irregular and poor yields caused some growers to seek new locations in which to raise seed, some at quite a distance from the Skagit. However, here too losses became heavy, and in some instances prohibitive. The seriousness of this situation was primarily responsible for the establishment in 1943, at Mount Vernon, of the Laboratory, recently redesignated as the Northwest Agricultural Laboratory.

Of the three leading insect pests of the cabbage seed crop in northwest Washington, the cabbage maggot, *Hylemia brassicae* (Bouché), is probably third in importance, being outranked only by the cabbage aphid, *Brevicoryne brassicae* (Linné.) and the cabbage seedpod weevil, *Ceutorhynchus assimilis* Payk. Cultural practices prevalent in the district have long favored the development of the cabbage maggot. These have provided an abundance of host plants and a continuous supply of succulent material on which the maggots feed. In addition there is a considerable acreage of turnips, rutabagas, and radishes in the area, and these contribute toward building up a large population of flies.

Seed beds, to supply planting stock for the following year's crop, are planted and the young plants are growing before the seed producing plants are fully matured and harvested. The small plants in the seed bed are very susceptible to injury by the maggots. If infestation is not prevented, the transplants will carry maggots with them into the seed fields. Apparently the newly set transplants in the

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field are the most susceptible of all to injury by the maggots. Planting stock is transplanted to the fields at a time fourth and fifth broods of flies are on the wing. Transplants need a month or longer to take root and develop enough to withstand the effects of an attack. As many as 60 per cent of these transplants may be lost because of maggot injury.

The Skagit area lies directly east of the

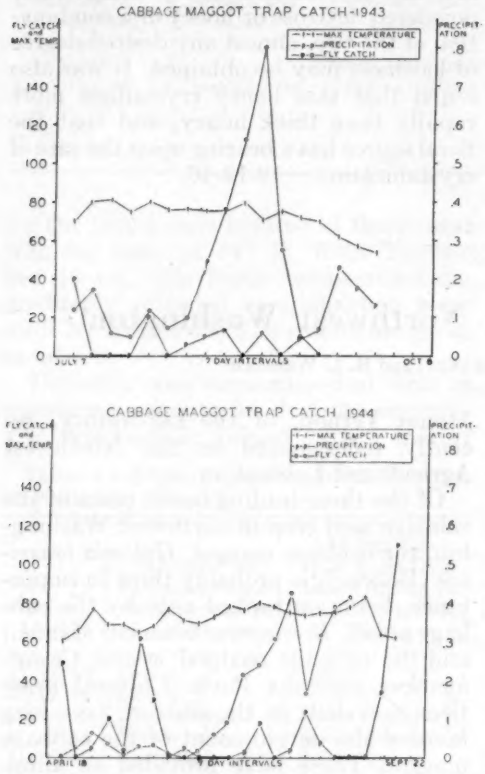

FIG. 1.—Fly trap catches. Above, 1943; Below, 1944.

Straits of Juan de Fuca and there is mountain range to break the effect of the prevailing westerly winds. Although this area has a maritime climate, it is subject to sudden changes in the weather. These climatic conditions apparently determine to a large extent the damage that may be caused by the maggot. Data to date show that the flies are not very active on days when the temperature is low or the precipitation high, or when both occur on the same day (Fig. 1). If these conditions prevail during the period when the transplants are becoming established in the field, there may be little or no maggot injury. However, if the temperature remains fairly high and constant and the precipitation is low during the period, the flies will be very active and there may be a serious loss of transplants (Fig. 1).

HISTORICAL.—Experiments on cabbage maggot control in Washington were begun in 1913 on Vashon Island.[1] The results of these tests indicated that cabbage plants could be protected by scattering naphthalene flakes about the plants at the rate of one teaspoonful to each plant, every eight or ten days. However, naphthalene proved to be detrimental to the growth of the cabbage plants.

During the summer of 1914, E. B. Stookey,[2] tested a number of materials and combinations of materials as controls for the cabbage maggot. The use of tarred felt discs gave an especially high percentage stand.

Experiments on the control of the cabbage maggot in western Washington were continued in 1914 by M. A. Yothers.[3] The following practices were suggested as being beneficial: (1) start the plants in the fall and transplant to the field in February or March, thus giving them a chance to get ahead of the maggots; (2) place tarred paper discs about the stems close to the ground as soon as the plants are set in the field; (3) start plants late enough to be transplanted into the field after the middle of May; and (4) grow radishes for home use in screened beds. Naphthalene flakes proved to be undesirable as a repellent because of the expense, volatility, and injury to the plants.

The efficiency of calomel as a treatment for controlling the cabbage maggot was demonstrated by Hugh Glasgow (1929) in New York. When used to protect cauliflower, a dust consisting of 4 per cent calomel and 96 per cent gypsum gave 100 per cent clean plants. Coating the seed with finely ground calomel gave 100 per cent clean plants, and drilling the 4 per cent dust with the seed also gave 100 per cent clean plants.

Neely Turner (1931) in Connecticut tested the effectiveness of rotenone as a control for the cabbage maggot. The rotenone was used in three concentrations and was applied as a suspension in water

[1] See Bulletin 11, page 14–15, Washington Agricultural Experiment Station, 1914.
[2] Western Washington Expt. Station, Monthly Bulletin, Vol. 2, No. 12, p. 45, 1915.
[3] Bulletin 127, pp. 33–35, Washington Agricultural Experiment Station, 1915.

from an acetone solution. The results of these tests showed that rotenone at the rates of 1 to 2500 and 1 to 5000 increased the yield of cabbage as compared with the yield of check plots. This was true even in the case of a single treatment. Rotenone at 1 to 10,000 was not so effective.

R. B. Friend (1912) found that a dust consisting of 4 per cent calomel plus 96 per cent gypsum gave as good results as a solution of bichloride of mercury (1 oz. in 10 gals. water) as a control for the cabbage maggot on radishes and was much cheaper and easier to apply.

B. B. Fulton (1942) stated that corrosive sublimate solutions at various concentrations, and calomel as a suspension in water (at 1 oz. to 10 gallons) or as a dust in talc (at 1:20 by weight) were all effective for maggot control when applied three times at weekly intervals. A suspension of yellow mercuric oxide (1 oz. in 10 gals.) in water was equal to corrosive sublimate at the same concentration. Delayed planting, crop rotation, and other cultural methods were also recommended.

W. D. Whitcomb (1944) suggested the use of corrosive sublimate solution 1 to 1920, applied at the rate of one gallon to 40 feet of row for seed bed treatment, and calomel with talc for pre-transplanting treatments. Repellents, toxic dusts, and toxic liquid drenches are discussed from the standpoint of field control. Crop rotation, fall plowing and similar cultural practices helped to reduce losses.

The above resume of work on the control of the cabbage maggot indicated the need for further investigational work in the Skagit area of northwest Washington, in order to determine whether or not the materials and methods used in other parts of the country would be applicable here. Furthermore, the growers had formed the habit of utilizing naphthalene for maggot control apparently on the basis of the earlier work and because of its use for carrot rust fly control. Naphthalene was not effective and growers began doubling their plant bed acreage in order to offset maggot injury.

A project on the control of the cabbage maggot in the Mount Vernon area was initiated in 1943: (1) to determine the effectiveness and proper use of the mercurials, (2) to search for less expensive substitute materials, (3) to develop rates and methods of applications, and (4) to study the effects of cultural practices on control.

MATERIALS AND METHODS.—Materials.

Calomel—Mercurous chloride—U.S.P. J. T. Baker Chemical Company, Philipsburg, New Jersey, 1943.

Mild mercurous chloride—U.S.P. Mallincrodt Chemical Works, St. Louis, Missouri, 1944.

Lime—Super hydrated, 95 per cent calcium hydrate. Roche Harbor Lime and Cement Company, Roche Harbor, Washington.

Creosote—Commercial coal tar creosote. J. E. Berkheimer Co., Tacoma, Washington, 1943.

Atco, commercial creosote oil. American Tar Co., Seattle, Washington, 1944.

Nicodust 3.6 per cent nicotine dust. Made with nicotine sulfate 40 per cent and hydrated lime in the laboratory.

Lead arsenate—Standard acid. Chipman Chemical Co., Boundbrook, New Jersey.

Pestex Dust—7.5 per cent *No. 506 oil* in talc. Hayden Chemical Corp., New York, N. Y. *506 oil* is the residue left after redistilling beechwood creosote.

Magotite Dust—Harry Leckenby, Seattle, Washington. Containing: tar acids, 1.7 per cent, gypsum, 5 parts, diatomaceous earth, 1 part.

Diphenylamine—Purified, General Chemical Co., New York, N. Y.

Gypsum—Standard Gypsum Co., Seattle, Washington.

Carco—Emulsible tar oil spray—Getzum Products, Sumner, Washington. Containing: coal tar—70 per cent, neutral oils—20 per cent, water—10 per cent, phenols—4 per cent of the total.

Summer oil—Oil emulsion. California Spray Chemical Corp. 98 per cent light oil, of a high unsulfonable residue of 90 to 95 per cent.

Dormant oil—Paste emulsion, 90 per cent heavy oil, 70–77 U.R., and 100–110 Saybolt viscosity. Union Oil Company. 1943.

Dormant oil—Paste emulsion, 98 per cent heavy oil of 140–145 Saybolt viscosity, Sherman Williams, Wenatchee, Washington.

Carbolic acid—*Red Band Sanitary Fluid.* Phenol coefficient 5 by F.D.A. method. Van Waters & Rogers, Seattle, Washington.

Dichlorethyl ether—Brawn Corporation,

Los Angeles, California. Beta beta dichloroethyl ether.

Amine 220—Emulsifier. Carbide and Carbon Chemical Corp., New York, N. Y.

Berako—Emulsible rotenone spray concentrate—Chipman Chemical Co., Boundbrook, New Jersey. Containing: rotenone—2.5 per cent, other extractives 6.25 per cent, triethanolamine oleate—12.4 per cent, inert—78.85 per cent.

DDT—*Gesarol A 20*—Geigy Co., Inc., New York, N. Y. 20 per cent DDT. A dry base spray product. 1–2 oz. "*Eriopon N*" (wetting agent) added per 100 gallons when spraying cabbage.

DDT—*Gesapon No. 18*—Geigy Co., Inc., New York, N. Y. A 5 per cent dichlorodiphenyl-trichloroethane product with emulsible oil base.

Sodium Cyanide—*Cyanogen*. Scientific Supplies, Seattle, Washington.

Crude Naphthalene—Portland Gas and Coking Company, Portland, Oregon.

Pine Tar—W. P. Fuller Co., Inc., Tacoma, Washington.

Coal Tar—T. E. Berkheimer Co., Tacoma, Washington.

Visko D 24—Paste type rotenone spray concentrate—Visko Inc., Sumner, Washington. Rotenone in oil base with an emulsifier. Containing: Rotenone 1.25 per cent, other Derris root extractives—6.4 per cent, light mineral oil—25 per cent, solvents and amendments—30 per cent, inert—not more than 40 per cent.

Dinitro phenol—Water soluble triethanolamine salt—Dow Chemical Company, Midland, Michigan.

Boron 20 per cent—98–100 per cent pure sodium borate—Agricultural mesh. Pacific Coast Borax Company. Los Angeles, California.

Carbon disulfide—Merck & Company, Inc., Rahway, New Jersey. An emulsible spray base containing 50 per cent carbon disulphide, 45 per cent Mineral Seal oil, and 5 per cent oil soluble emulsifier.

Santobane A—Monsanto Chemical Co., 1700 S. Second Street, St. Louis, Missouri. An emulsible spray base containing 50 per cent N,N amyl benzyl cyclohexylamine, 45 per cent Mineral Seal oil, and 5 per cent oil soluble emulsifier.

METHODS.—The control experiments have been conducted in the cabbage plant beds of the LaConner flats district of Skagit County. These plant beds consisted of several acres each and were seeded during the month of June (dates varying with the variety). The rows were spaced from 9 to 12 inches apart and cultivation was by manually operated garden tools. Each experimental plot consisted of five rows, fifty feet long. The plots were separated by five untreated rows. In 1945, the plots were shortened and 25-foot rows were used. Each treatment was replicated three times and three applications were made at 10-day intervals. The first application was made as soon as the young seedlings had broken through the soil. The dusts were applied in a thin stream adjacent to the plant stems by the means of a *Planet Jr.* fertilizer attachment with the delivery tube set to reach within an inch of the soil surface. The liquids were applied as a drench along side the plants by means of a wheelbarrow sprayer from which the spray nozzle had been removed. Plant counts were made two weeks after the final application of materials to determine the number of infested plants. In 1945, plant counts were made 25 days after final application of materials.

LIFE HISTORY.—To estimate daily fly populations, bait traps were placed at random throughout the plant beds and seed fields. These consisted of common tin cans which were buried in the soil for about three quarters of their depth. The bait consisted of a mixture of 1 quart of molasses, 1 quart of corn syrup, and 2 quarts of water with about one-fourth cake of yeast added. The cans were filled to within about one-half inch of the top with this mixture. A daily check of these traps throughout the season gave a fairly accurate estimate of the flies present in the area. These data made it possible to determine the number of broods or peak populations in the district and to establish correlation between the effect of precipitation and temperature on the fly catch.

Flies from over-wintering puparia emerged in the Skagit area from April 1 to April 15. Data gathered during the past 3 years show that there are either four or five broods of flies present each season, depending on the climatic conditions prevalent. The first brood of importance appears from late April to early May, a second but smaller brood in late May, a

third from late June to the middle of July, a fourth in August, and a fifth brood in September (Figs. 1 and 2). Sometimes one of these broods is eliminated by unfavorable temperatures and precipitation.

CHEMICAL CONTROL.—The first season's investigations (Table 1) indicated that the calomel-lime dust gave the greatest reduction in maggot infestation. Several concentrations of the calomel in lime dust were tested the following seasons since the high concentration of 2:3 used in 1943 was prohibitive in cost. Other materials which showed promise were the calomel suspension, creosote lime dust, summer oil emulsion, dormant oil emulsion. *Carco*, *Magotite*, and *Pestex oil*. Although the rotenone in liquid form and the calomel seed treatment did not show much promise, they too were tested.

Corrosive sublimate is one of the standard treatments for cabbage maggot control. Corrosive sublimate reduced the maggot infestation 73.3 per cent when applied as a drench. Infestation in the untreated check was 47.9 per cent. Since the calomel suspension gave as good control as the corrosive sublimate solution. the corrosive sublimate was dropped in favor of the calomel in subsequent years.

The second season's investigations, 1944 (Table 1) showed quite conclusively that the calomel lime dust was the most efficient combination of materials tested. The checks in this series of treatments showed an average maggot infestation of 49.9 per cent. Calomel lime dust at a concentration of 2:3 gave a maggot control of 97.0 per cent; at 1:9 it gave a control of 93.0 per cent; and at 1:24 it gave a control of 76.0 per cent.

The incorporation of the calomel with gypsum at 1:24 resulted in a slightly increased control in comparison with that obtained with calomel and lime at the same concentration. However, the principal advantage in the use of the gypsum as a diluent for the calomel is the fact that it flows more readily since it is coarser, heavier and does not have the adhesive properties of lime.

In 1944, powdered bentonite was added to the calomel suspension at the rate of one-half ounce to 10 gallons, in order to hold the calomel in suspension. When applied as a drench adjacent to the plants, the use of this material resulted in a maggot control of 90.0 per cent, but when applied as a spray it resulted in a control of 54.9 per cent. This indicates that spraying probably does not place enough of the material near the plant stems to insure maggot control.

The second season's investigations also indicated that creosote-lime dust (5 per cent creosote), summer oil emulsion at concentrations of 2 per cent and 5 per cent, 2 per cent dormant oil emulsion, *Magotite*, seed coated with calomel at planting time, rotenone (*Berako 1–400*), and *Pestex*—lime—5 per cent No. 506011 did not give satisfactory maggot control (Table 1). When the concentration of creosote was increased from 5 per cent to 7.5 per cent in the creosote-lime dust, the combination showed some value in maggot control, but plant stunting and plant kill resulted from its use in some instances.

Lime alone and lead arsenate-lime dust (1:3) gave no maggot control. Of the other four materials investigated and meriting further trial, the 5 per cent diphenylamine in lime showed the most promise since it gave a maggot control of 67.9 per cent. The dichloroethyl ether suspension (1:236) resulted in a control

Table 1.—Cabbage maggot control experiments, 1943, 44 and 45.

TREATMENTS	AVERAGE PER CENT INFESTATION	PER CENT CONTROL
1943		
Check (Untreated)	47.9	0.0
Calomel Lime Dust 2:3	5.5	88.5
Calomel Suspension 1 oz. in 10 gals. water	13.5	71.8
Calomel Corn Starch Seed Treatment 4 oz. to 1 lb. seed	36.5	23.8
Corrosive Sublimate Solution 1 oz. in 10 gals. water	12.8	73.3
Sodium Cyanide Solution 1 oz. in 25 gals. water	32.3	32.6
Crude Naphthalene Flakes	27.2	43.2
Firwood Sawdust	29.3	38.8
Firwood Sawdust—5 per cent Pine Tar Oil	21.9	54.3
Firwood Sawdust—5 per cent Creosote	18.8	60.8
Firwood Sawdust—5 per cent *No. 506 Pestex Oil*	22.2	53.7
Visko D-24	31.8	33.6
Five per cent Creosote in Lime	13.7	71.4
Dormant Oil 2 per cent	24.2	49.5
Summer Oil 2 per cent	16.3	66.0
Magotite	15.8	67.0
Carco	20.6	57.0

Table 1.—(*Continued*)

Treatments	Average Per Cent Infestation	Per Cent Control
1944		
Check (Untreated)	49.9	0.0
Calomel Seed Treatment 1:1 by weight	44.7	10.4
Calomel Lime Dust 2:3	1.5	97.0
Calomel Lime Dust 1:9	3.5	93.0
Calomel Nico Dust 1 calomel : 19 nicotine lime dust, 3.6% nicotine	15.0	69.9
Calomel Lime Dust 1:24	12.0	76.0
Calomel Gypsum Dust 1:24	10.5	79.0
Calomel Suspension Spray	22.5	54.9
Calomel Suspension Drench	5.0	90.0
Creosote Lime Dust 5 per cent creosote	45.5	8.8
Creosote Lime Dust 7.5 per cent creosote	20.5	58.9
Lead Arsenate Lime Dust 1:3	64.0	0.0
Pestex Lime Dust 5 per cent no. 506 Pestex Oil	56.5	0.0
Diphenylamine Lime Dust 5 per cent diphenylamine	16.0	67.9
Lime	49.5	0.8
Magotite	36.0	27.9
Summer Oil 2 per cent	56.5	0.0
Summer Oil 5 per cent	40.5	18.8
Dormant Oil 2 per cent	57.0	0.0
Dichloroethyl ether Emulsion	32.5	34.9
Berako	55.5	0.0
Gesapon 18	20.5	58.9
Gesarol A-20	22.0	55.9
Carco	40.5	18.8
1945		
Check (Untreated)	84.9	80.0
Calomel Gypsum Dust 1:19	10.7	87.4
Calomel Gypsum Dust 1:24	10.7	87.4
Calomel Gypsum Dust 1:30	11.3	87.6
Calomel Suspension 1 oz. in 10 gals. water	20.0	76.4
Diphenylamine Gypsum Dust 5 per cent diphenylamine	13.3	84.3
Diphenylamine Lime Dust 5 per cent diphenylamine	7.0	91.8
DDT Dust 3 per cent DDT	71.3	16.0
Dichloroethyl ether Emulsion	60.7	28.5
Carbon disulphide Emulsion 50 per cent CS_2 in emulsible oil 1–200	77.3	9.0
Santobane A Emulsion 50 per cent *Santobane A* in emulsible oil 1–400	80.7	5.0

of 34.9 per cent. *Gesapon 18* when diluted 1–100 resulted in a 64.7 per cent maggot control and *Gesarol A 20* when used at the rate of 2 pounds per 100 gallons (0.5 per cent DDT) resulted in a control of 55.9 per cent. These results indicated some control value for these two DDT materials.

The 1945 investigations again showed (Table 1) that the calomel-gypsum dusts gave the most satisfactory cabbage maggot control. When the calomel was present at both 4 per cent (1:24) and 5 per cent (1:19) concentrations, the maggot control was 87.4 per cent when an average infestation of 84.9 per cent was present in the untreated checks. In comparison, 86.6 per cent control was obtained with a dust containing calomel at a concentration of 3.3 per cent (1–30). In 1944, a dust containing 4 per cent calomel resulted in a substantially poorer control than was obtained by dusts containing higher concentrations of calomel. This was apparently due to the fact that the applications were made by hand during the past season (1945) which resulted in a more accurate placement of the material. A concentration as low as 3.3 per cent will apparently control the cabbage maggot if more care is used in placing the material. The calomel suspension (1 oz. in 10 gals. water) gave only 76.4 per cent control as compared to a control of 87.4 per cent for the calomel-gypsum dusts. This seems to indicate that the calomel-gypsum dusts are more dependable maggot controls than the standard calomel suspension.

Diphenylamine resulted in 84.3 per cent control when used at a concentration of 5 per cent with gypsum and a 91.8 per cent control at the same concentration, but with hydrated lime as the diluent. However, when used with hydrated lime this material caused a severe blackening of both the cortex and stele of the roots, severe stunting, and a plant kill of 50 to 60 per cent. When used with gypsum, only moderate blackening and no stunting or kill was observed.

None of the several other materials investigated this season showed any substantial maggot control. Dichloroethyl ether (1:236) gave 28.0 per cent control and was highest of the remaining materials. The *Gesarol A 3* dust (3 per cent DDT) gave a control of 16.0 per cent. The *Santobane A* emulsion (1–400) and the carbon disulfide emulsion (1–200) which were both used as liquids, gave only 5 and 9 per cent control respectively.

APPROXIMATE COST OF TREATMENTS.—The dusts have been used at the rate of 1 pound per 100 feet of plant bed row or about 435 pounds per acre. Thus the cost of an application of calomel-lime or calo-

mel-gypsum dust in the plant bed at a concentration of calomel to gypsum or lime of 1:19 would be about $144.00 an acre for the entire season as based on current prices for calomel. This cost seems to be prohibitive. However, when it is remembered that one acre of plant bed supplied plants for an average of 70 acres of seed field, the cost of treatment per acre of seed field is lowered to approximately $2.00.

The drenches were applied at the rate of 10 gallons per 500 feet of row or 871 gallons an acre at a cost of about $36.00 an acre, a season, for the calomel suspension. These estimates are exclusive of labor costs in the application of the material. Labor costs would necessarily be much greater with the drenches than with the dusts.

CULTURAL CONTROL.—A plant bed was established in an isolated area in 1943, well removed from any fields in which cruciferous seed crops were growing, for the purpose of determining the effect of this practice on the control of insect pests and plant diseases. Counts made in these beds have shown a maggot infestation of 5 to 10 per cent as compared with an infestation of 50 to 60 per cent in plant beds located in the seed area where the population was high. Apparently isolation of plant beds will, for the present at least, reduce the maggot infestation to a minimum, and prevent the carry over of maggots into the transplanted fields. However, control measures should be applied in the transplanted fields immediately after placing the plants.

Eventually the isolated areas will probably become infested with maggots so that chemical control will be necessary. This statement is borne out by the past season's survey which included one isolated plant bed where cabbage plants had been grown continuously throughout two seasons. The data show that certain sections of this plant bed where cabbage had been grown throughout the year and for several years will result in an increase in maggot population to the point where isolation will no longer effectively control the maggot.

As far as it is known to date, biological control in the form of parasites or predators plays no part in the control of the cabbage maggot.

SUMMARY.—1. Control of the cabbage maggot in the plant beds and in the transplants in the cabbage seed producing area of the Northwest Washington was studied from 1943 to 1945.

2. The use of calomel-gypsum dust at concentrations of 1 to 19 and 1 to 24 resulted in satisfactory and practical maggot control. Gypsum apparently makes a more efficient diluent for the calomel than does lime.

3. A calomel suspension (1 oz. to 10 gals. water) gave fair and practical maggot control and is considered an alternative control measure. The calomel suspension gave an inferior control when applied as a spray rather than a drench.

4. The rate of application for the calomel-gypsum dust, which proved to be satisfactory in the cabbage plant beds, was 1 pound to 100 feet of row or 435 pounds per acre. The rate of application for the calomel suspension was 1 gallon per 50 feet of row or 871 gallons per acre.

5. A 5 per cent diphenylamine dust with gypsum as the diluent resulted in control comparable to that obtained by use of the calomel-gypsum dust. Severe injury may result, however. Gypsum seems to make a safer combination than lime.

6. Timely applications of the treatments should be made at 10 day intervals, beginning when the seedlings first break through the soil.

7. Substitute materials worthy of additional investigations are: (1) 5 per cent diphenylamine with gypsum, (2) dichlorethyl ether at higher concentrations and (3) DDT at higher concentrations.

8. It is advisable to protect newly set transplants in the fields located in the seed producing area with a calomel-gypsum dust.

9. Plant bed isolation resulted in temporary maggot control, but maggot populations will probably build up under continuous use of the same bed.

10. Data based on daily fly catches indicate that when temperatures are lowered and precipitation is increased, the activity of the flies decreases and vice versa.

11. Data based on daily fly catches also indicate that either four or five broods of the cabbage maggot occur in this district, depending on prevailing climatic conditions.—8-1-46.

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The Mode of Absorption of Carbon Tetrachloride by Wheat[1]

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That a gaseous fumigant may be absorbed or dissolved in a product has been recognized for many years. Strand (1927), Fisk & Shepard (1938), Page & Lubatti (1940), Cotton *et al.* (1944), and others, have drawn attention to this problem and in some instances have attempted to measure the amounts taken up. Their data, however, were of such a nature that a determination of the type of reaction involved was impossible.

Fumigants usually are applied in the liquid state and are either sprayed uniformly over the surface of the product or released in known quantities at various points within the mass. Regardless of the mode of application, the liquid fumigant must vaporize to form a solution in air in which state its diffusion throughout the mass of the product must take place.

Present methods of comparing the toxic properties of fumigants are based on the knowledge that both time and concentration must be accurately controlled. If, for instance, the concentration of a gas used against a certain insect is decreased by a known amount, the exposure period must be proportionately increased if the same effect is to be produced. In the standard procedure for comparing the toxic properties of fumigants, the time of exposure is usually standardized and the concentration of the gas varied. The concentration of the fumigant can be controlled with a relatively high degree of accuracy because experiments are usually carried out on test insects enclosed in glass containers, and in the absence of absorbing materials.

While the data obtained in the above manner can be used for comparative purposes, they often prove of little value in practical fumigation, or studies regarding the mode of absorption, as the latter factor is dependent on equilibrium concentration and the former may or may not be. This equilibrium concentration, in turn, is dependent upon the quantity of gas taken up by the product. The extent of the absorption process is governed by the properties of the fumigant as well as by those of the material being fumigated. If some constituent of this material takes up the gaseous fumigant in some way, the fumigant will distribute itself between the two phases (air and liquid or solid) so that at equilibrium the concentration of the fumigant in the air phase may be considerably less than anticipated.

The need for more precise information on this problem has been adequately presented by Brown (1944). He points out the necessity for obtaining information of a purely chemical or physical nature on the reactions between fumigant and product. "Lack of this knowledge," he says, "has led to considerable confusion regarding the dosage applied and the actual concentrations obtained in practical fumigation."

The amount of certain fumigants taken up by the product can now be measured with a reasonable degree of accuracy. It should be borne in mind, however, that usually only data obtained after equilibrium has been reached between the fumigant and product, can be used for studying the types of reactions involved. A considerable length of time may be required to react an equilibrium state. For this reason equilibrium data may not be comparable to the time-concentration effects which various workers have established by bioassay.

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The experiments reported in this paper were designed to give data which could be subjected to theoretical treatment in an effort to determine the type of reaction taking place between carbon tetrachloride and wheat. In addition to the whole kernel wheat, some specially treated samples were used in these tests. The wheat was hand picked thus removing all small cracked, starchy, or shriveled kernels, and chaff and weed seeds. The resulting product represented a uniform sample which graded No. 1 Hard Dark Northern Winter Wheat.

The average composition of wheat grown in the Rocky Mountain States[1] is as follows: protein 13.3 per cent, fat 2.2 per cent, fiber, 4.1 per cent, nitrogen-free extract (by difference) 71.9 per cent, and ash 2.0 per cent. The germ comprises 2 to 3 per cent of the wheat kernel and has the following average composition (Structure and Composition of Foods, Vol. 1, p. 214, 1932): protein 35.24 per cent, fat 13.51 per cent, nitrogen-free extract 44.72 per cent, fiber 1.71 per cent, and ash 4.82 per cent. While these proportions will undoubtedly vary somewhat between samples, they do, nevertheless, serve as a valuable index to the composition of the material being fumigated.

Carbon tetrachloride was the fumigant selected for study as it was believed that, under the temperatures and pressures employed, this material would be relatively nonreactive chemically. This would eliminate the problem encountered by Page & Lubatti in which the fumigant (HCN) formed a chemical compound with a constituent of the product being fumigated.

METHODS.—A manometric method was devised whereby the amount of carbon tetrachloride taken up by the wheat could be accurately measured. By this method it was possible to measure the rate of uptake of the gas and to determine the point at which equilibrium had been established. The method consisted of introducing a known quantity of air saturated with carbon tetrachloride, at the temperature of the experiment, into a reaction flask which contained a weighed quantity of the wheat. The amount of carbon tetrachloride taken up by the wheat was calculated from measurements of the reduction in pressure in the reaction flask. Check determinations, using only air drawn from the cabinet, produced no pressure changes other than those brought about by fluctuations in barometric pressure, provided a constant temperature was maintained; therefore, any pressure changes in the reaction flask other than those produced by barometric fluctuations must have resulted from the removal of carbon tetrachloride vapor from the air-gas mixture which was introduced.

A constant-temperature cabinet large enough to hold ten 6-liter flasks was used in maintaining temperature control. In order to obtain reproducible results, it was necessary to maintain temperature control throughout the cabinet to within $\pm 0.1°$ C.

Five of the 6-liter flasks were used to provide the saturated air-carbon tetrachloride mixture. To obtain this mixture an excess of carbon tetrachloride was introduced into each flask. They were connected in series so that the air-gas mixture which was drawn off the top of one flask would be introduced into the bottom of the next in the series. In this way the air, saturated with carbon tetrachloride vapor, had to pass through all five flasks before it passed from the top of the last one into a reaction flask.

It is important that the reaction flasks be constructed so that no absorptive surfaces are exposed to the fumigant under test. Round-bottom pyrex flasks of approximately 6 liter capacity were used. Each was fitted with a ground glass stopper and four side arm outlets spaced evenly around the neck just below the glass stopper. Each side arm was provided with a glass stopcock. Two of these outlets were connected (through the wall of the cabinet) to manometers, one of which contained mercury and the other n-butyl phthalate. A third outlet was connected to the series of flasks containing the saturated air-carbon tetrachloride mixture while the fourth was connected to a vacuum pump. It was necessary to employ a glycerin-graphite mixture as the lubricant for both the stoppers and the stopcocks. Such materials as lanolin, petroleum jelly, high vacuum stopcock grease, etc. dissolved enough of the carbon tetrachloride vapor to introduce an appreciable error.

One of the reaction flasks containing the same amount of grain as the others was used as a check into which no carbon

[1] Food and Food Products, Vol. I, p. 615, 1944.

tetrachloride was introduced. Any small changes in temperature as well as barometric pressure changes could be obtained directly from this check flask. The values obtained from the reaction flasks could thus be corrected for these factors.

When the reaction flasks were evacuated and the saturated air-carbon tetrachloride mixture was allowed to rush in, the adiabatic contraction of the gases was found to be sufficient to necessitate the use of a correction factor. This correction factor was determined for each pressure to which the reaction flasks were evacuated. It was found that, under the particular conditions of these tests, air taken from the cabinet, and saturated air-carbon tetrachloride mixture, when introduced into the empty reaction flasks produced essentially the same amount of contraction. It was then possible to obtain the correction factor by introducing air from the cabinet into the reaction flask which contained a weighed quantity of grain. For all of the measurements a standard time of 1 minute was allowed for the gases to enter the reaction flasks.

In order to measure the amount of carbon tetrachloride taken up by the wheat and the rate at which this occurred, a given weight of the wheat was placed in each of the reaction and the check flasks. These were then placed in the temperature cabinet along with those containing the air-carbon tetrachloride mixture for 24 to 48 hours or until thermal equilibrium had been attained. The outlets on the reaction flasks to be treated were then closed except for the ones leading to the mercury manometer and the vacuum pump. After the desired pressure, as measured on the mercury manometer, was obtained in the reaction flask, the outlet to the vacuum pump was closed. The stopcock connecting the reaction flask to the flasks containing the saturated air-carbon tetrachloride mixture was then adjusted so that one minute was required for the air-gas mixture to enter and refill the partially evacuated flask. All of the stopcocks were then closed on both the reaction and the check flasks.

In order to follow the uptake of the carbon tetrachloride, the stopcock leading to the n-butyl phthalate manometer was opened at intervals and the reduction in pressure recorded in millimeters of n-butyl phthalate. At the same time a similar reading was taken from the check flask to be used in correcting the reading obtained on the reaction flask. The use of these sensitive manometers, as well as the minimizing of the possibility of leakage where long periods of time were involved, necessitated the practice of equalizing the pressure after each reading. This was accomplished by opening a stopcock in both the reaction and check flasks allowing cabinet air to enter until atmospheric pressure was attained. The stopcocks were then closed and kept so until the next reading was taken. In this manner the rate and amount of uptake could be followed until equilibrium had been established. Each measurement was made in duplicate and the average value reported.

Table 1.—Unground whole wheat (8 per cent moisture except where otherwise stated) and carbon tetrachloride (container 9 per cent full of wheat).

Fraction of Saturation of CCl_4 Vapor (f)	CCl_4 Absorbed (n_2) (Moles per Kg. of Wheat)	Moles of Solvent per Kg. of Wheat (n_1) (Calculated by Equation (1))
	(a) 20° C.	
0.557	0.0259	0.021
0.443	0.0175	0.022
0.320	0.0102	0.022
0.154	0.0049	0.027
	(b) 25° C.	
0.591	0.0292	0.020
0.466	0.0202	0.023
0.348	0.0108	0.020
0.196	0.0034	0.014
	(c) 30° C.	
0.589	0.0360	0.025
0.466	0.0246	0.028
0.358	0.0116	0.021
0.176	0.0047	0.022
	(d) 35° C.	
0.646	0.0365	0.020
0.512	0.0240	0.023
0.372	0.0121	0.020
0.201	0.0033	0.013
	(e) 35° C. 16% Moisture	
0.606	0.0378	0.024
0.518	0.0233	0.022
0.372	0.0123	0.021
0.194	0.0038	0.016
	(f) 25° C.*	
0.695	0.0206	0.009
0.542	0.0136	0.011
0.405	0.0063	0.009
0.216	0.0016	0.006

* Whole wheat previously extracted by continuous extraction with methyl alcohol.

The weight of the carbon tetrachloride taken up by a given quantity of wheat at 25° C. was obtained according to the following sample calculations. For a given determination the reduction in pressure in the reaction flask after partial evacuation (difference in mercury levels prior to filling with the air-gas mixture) was found to be 210 mm. and the barometric pressure 630 mm. of mercury. The vapor pressure of carbon tetrachloride at 25° C. is 114.5 mm. of mercury; therefore, the pressure of the carbon tetrachloride in the reaction flask after allowing the saturated air-carbon tetrachloride mixture to refill it was $114.45 \times 210/630$ or 38.13 mm. Then by substitution in the perfect gas equation $g = PVM/RT$ where g = grams of fumigant; P = partial pressure in mm. of mercury, of carbon tetrachloride in the flask; V = volume of the flask in cc. less the space occupied by the wheat (calculated from density of the wheat); M = molecular weight of the fumigant; R = universal gas constant cc.-mm.; and T = absolute temperature. The value for the grams of carbon tetrachloride introduced into the reaction flask was obtained; $g = 38.13 \times 5359 \times 153.83/62400 \times 298.1 = 1.69$ gms.[1]

In order to obtain the weight of carbon tetrachloride taken up by the grain, the total reduction in pressure in the reaction flask during the course of the test was used. In the above example it was found to be 110 mm. n-butyl phthalate. This value was converted into mm. of mercury by use of the conversion factor 0.077, and equals 8.47 mm. of mercury. The ratio then of $1.69 \times 8.47/38.13$, or 0.38 gm., equals the grams of carbon tetrachloride taken up by the wheat.

The data presented in table 2 were obtained by weighing the carbon tetrachloride in a vial and then introducing the vial and its contents directly into the reaction flask. The quantities of carbon tetrachloride introduced were such that complete volatilization would be assured before equilibrium conditions were attained. The amount of carbon tetrachloride taken up by the wheat was then obtained manometrically by the method previously described. The errors introduced by this method of applying the fumigant are not significant where relatively large amounts of materials are involved, but use of this method is restricted to the less volatile types of fumigant. It is also impossible to follow the rate of the reaction when this method is employed. These tests were made on both cleaned and uncleaned wheat. The latter contained a considerable quantity of cracked kernels, weed seed, chaff, shriveled and starchy kernels.

Table 2.—Redetermination on unground whole wheat (8 per cent moisture) and carbon tetrachloride, with container 97 per cent full of wheat—25°C.

Fraction of Saturation of CCl_4 Vapor (f)	CCl_4 Absorbed (n_2) (Moles per Kg. of Wheat)	Moles of Solvent per Kg. of Wheat (n_1) (Calculated by Equation (1))
	(a) Uncleaned Wheat	
0.548	0.0275	0.023
0.526	0.0262	0.023
0.532	0.0260	0.023
	(b) Cleaned Wheat	
0.530	0.0261	0.023
0.523	0.0262	0.024

A series of determinations were made on the uptake of carbon tetrachloride by ground wheat. These were carried out to measure the effect of changing the physical state of the absorbent without changing its composition. The same wheat as described for the preceding experiments was ground in a *Hobart Mill* with a No. 5 burr setting. Some characterization of particle size may be ascertained from the following results which were obtained by screening a 500 gm. sample:

[1] DEFINITIONS OF SYMBOLS USED IN FORMULAE AND TABLES.

n_1 moles of effective solvent per kilogram of wheat (equilibrium).
n_2 total moles of absorbed fumigant per kilogram of wheat (equilibrium).
n_2' extra moles of fumigant absorbed per kilogram of wheat (equilibrium) after grinding wheat and establishing given equilibrium vapor concentration.
c concentration of fumigant vapor (equilibrium) (moles per liter).
c_s concentration of saturated fumigant vapor at temperature T (moles per liter).
f fraction of saturation of fumigant vapor (equilibrium) ($f = c/c_s$).
P_s vapor pressure of the liquid fumigant at temperature T (mm. of mercury).
T absolute temperature.
R universal gas constant (62.4 liter-mm. per degree).
a distribution coefficient, defined by $a = n_2/c^b$.
b a constant in the equation defining a.
V total volume of wheat container (in liters).
D true density of the wheat (on "compressed" basis) (grams per cc.).
D' apparent density of the wheat (on "bulk" basis) (grams per cc.).
D fraction of the total volume of the container occupied by wheat (on "bulk" basis).
M molecular weight of the fumigant.
N total grams of fumigant introduced.

Sieve	Per Cent Remaining on Sieve
30XX G.G.	22.0
50XX G.G.	47.0
70XX G.G.	14.0
12XX Silk	10.0

The remaining 7.0 per cent passed through the 12XX silk bolting cloth. The results of the tests on ground grain may be seen in table 3.

Determinations were also made on whole grain wheat which had been continuously extracted with methyl alcohol in a Soxhlet apparatus for a period of 96 hours. A portion of the extracted wheat was ground in a similar manner to that described above and the amount of carbon tetrachloride taken up by it was determined.

Experimental Results and Theoretical Treatment.—It may be assumed that a vapor absorbed by wheat will be held in one or more of the following ways: in an ideal solution, in a non-ideal solution, or by surface absorption. It will be shown that the experimental results of this investigation can best be explained by assuming that the carbon tetrachloride was retained by unground wheat almost entirely in the form of a nearly ideal solution, but by ground wheat at least partially in some other way.

Unground Wheat at Equilibrium.—It is not only possible but probable that in wheat the fat present would form nearly ideal solutions with carbon tetrachloride. The assumption of an ideal solution at equilibrium leads immediately to Raoults' Law,

$$f=\frac{n_2}{n_1+n_2}. \qquad (1)$$

This equation expresses the extent of absorption by use of a single constant n_1, the effective moles of solvent, for the absorbed fumigant, present in each kilogram of wheat. n_1 may be expected to be constant at all temperatures for a given type of wheat, and to vary within perhaps rather narrow limits for all wheat. It will be noted that equation (1) holds for all temperatures, all concentrations, and all absorbable vapors, provided only that the conditions for a nearly ideal solution are fulfilled. By the substitution of sufficient experimental data into equation (1), the constancy of n_1 may be tested and its best value for a given type of wheat may be determined. Values of f can be calculated from its definition,

$$f=c/c_0,$$

for which c_0 is calculated from the vapor

Table 3.—Ground whole wheat (8 per cent moisture) and carbon tetrachloride (container 9 per cent full of wheat).

Fraction of Saturation of CCl_4 Vapor (f)	Total CCl_4 Absorbed (n_2) (Moles per kg. of Wheat)	"Extra" CCl_4 Absorbed Compared with Unground Wheat (n_2') (Moles per kg. of Wheat)	Distribution Coefficient (a) (Based on Total CCl_4 Absorbed)	Moles of Solvent per kg. of Wheat (n_1) (Based on Total CCl_4 Absorbed; Calculated by Equation (1))
		(a) 20° C.		
0.382	0.0356	0.0219	18.8	0.058
0.294	0.0276	0.0184	18.9	0.066
0.207	0.0180	0.0122	17.5	0.069
		(b) 25° C.		
0.444	0.0410	0.0233	15.0	0.051
0.342	0.0297	0.0182	14.2	0.057
0.222	0.0202	0.0139	14.8	0.071
		(c) 30° C.		
0.522	0.0422	0.0181	10.7	0.039
0.382	0.0326	0.0189	11.3	0.053
0.262	0.0214	0.0136	10.8	0.060
		(d) 35° C.		
0.558	0.0480	0.0200	9.4	0.038
0.414	0.0362	0.0205	9.6	0.051
0.288	0.0232	0.0142	8.8	0.057

pressure of the liquid at the pertinent temperature by the perfect-gas law,

$$c_0 = P_0/RT.$$

All the equilibrium data obtained for carbon tetrachloride vapor and unground wheat are given in tables 1 and 2 in terms of n_2 and f. The values of n_1 were calculated from equation (1). Each line in tables 1 and 2 represents the average of two determinations of approximately the same concentration.

The hypothesis that the absorbed carbon tetrachloride was held in the unground wheat in the form of an approximately ideal solution is supported by the lack of a particular trend in the values of n_1 with changing concentration or changing temperature. It would be characteristic of ideal solutions that the heat of absorption of carbon tetrachloride vapor would equal the heat of condensation of the vapor to pure liquid carbon tetrachloride. It may be of interest that from the temperature coefficient of table 1 was obtained a heat of absorption differing only one per cent from the heat of condensation to liquid carbon tetrachloride.

The average value of n_1 in tables 1 and 2 for unground, unextracted whole wheat is 0.022 (omitting the last value of each set of four because of the magnification of experimental errors).

Sullivan (1940) reports some analysis of samples of wheat-germ extracts which show the lipids to consist largely of triglycerides of certain higher fatty acids, lecithins, and small amounts of certain sterols. If this is representative of the lipids of whole wheat, the average molecular weight of these fats and alcohols is about 850. (The exact proportions of the various triglycerides is not of critical concern here, since their individual molecular weights do not differ widely.) On the basis of this figure, 0.022 mole of solvent per kilogram of wheat indicates that the effective solvent composed 1.9 per cent of the wheat by weight, a figure in good agreement with the report of Food and Food Products (ibid.), that Rocky Mountain wheat is 2.2 per cent fat. On the other hand, table 1 (*f*) shows an average value of n_1 of about 0.010, indicating that the extraction removed more than half of the effective solvent.

Figure 1 affords a comparison of the values of n_2 and f (of table 1 (a) to (d)) with the curve representing equation (1) for a value of n_1 of 0.022. Since three weeks were often required for the establishment of virtual absorption equilibrium, some of the points may be in error because equilibrium had not quite been reached. Although the spread of points for some of the higher concentrations is too great to indicate a very definite trend

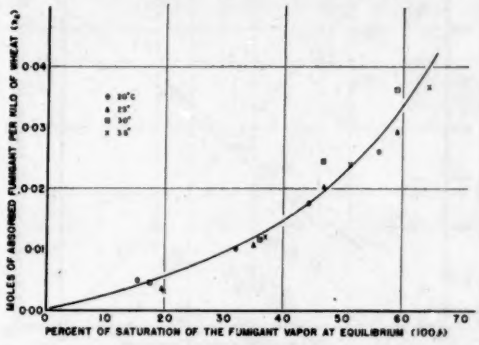

FIG. 1.—A comparison of the values of n_2 and f from table 1 (a) to (d) showing the four concentrations at four temperatures.

to the curvature of the best curve through the experimental points (without the assumption of ideal solutions), the experimental points definitely indicate a curve concave upward, in agreement with the theoretical curve of the figure, when it is recalled that regardless of the type of absorption assumed, the curve must pass through the origin. (A typical surface absorption, on the other hand, would have led to a curve concave downward.)

The wide applicability of equation (1) raises the important question as to what fumigants and conditions result in nearly ideal solutions with the wheat fat. Data for similar solutions are not abundant; however, partial pressures, at 50° C., of solutions of carbon tetrachloride and a simple ester, ethyl acetate, are recorded in the *International Critical Tables* (Volume 3, page 285). The partial pressure of neither carbon tetrachloride nor ethyl acetate rises above that predicted by Raoults' Law, the calculated amount of ester would not be much below the true amount except for those solutions whose carbon tetrachloride vapors were below 40 per cent of saturation. Analogously, it will be noted from table 1 that in each

set of four the lowest concentration (where f is considerably below 0.40) usually gives a lower value of n_1 than given by the higher concentrations.

These facts suggest that with substitution for n_1 of a value obtained from studies with carbon tetrachloride and wheat, equation (1) may predict an amount absorbed which is in error by a considerable

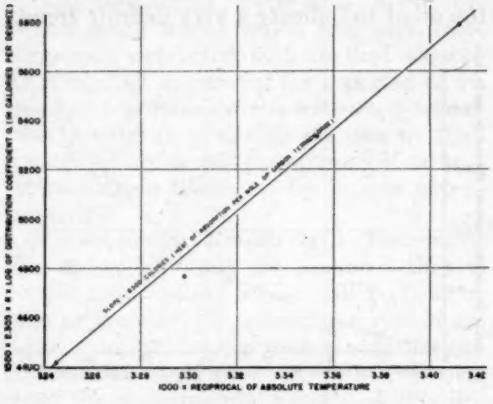

FIG. 2.—Showing the heat of absorption per mole of CCl_4 with the values of the distribution coefficient a (assuming b equal to unity).

percentage if the fumigant being used has a boiling point below room temperature, since for ordinary pressures of fumigant vapor, f will then be relatively small. In such cases the percentage of the introduced gas which is absorbed will be so much smaller than in the case of carbon tetrachloride that the predicted equilibrium gas concentration, which is the quantity of most practical interest, may still be fairly accurate on a percentage basis. However, in view of the fact that carbon tetrachloride is a non-polar liquid, large deviations from Raoults' Law may be expected for fumigants which have large dipole moments.

Ground Wheat at Equilibrium.—The equilibrium data are given in table 3 for carbon tetrachloride vapor and ground samples of the same wheat recorded in tables 1 and 2. As in table 1, each line represents the average of two determinations.

It can be shown that if the carbon tetrachloride is actually absorbed to form an ideal solution, the constant b in Freundlich's equation,

$$n_2 = aC^b, \qquad (2)$$

will have variable values but will equal two when $f=0.5$. Since the equilibrium results of this paper fall around this value of f, the values of b of approximately two which were found in the case of unground wheat are explained. For the ground wheat, however, the values of b are approximately unity. This fact, together with the consequent consistent drift of the values of n_1 calculated from Raoults' Law and given in table 3, indicates that formation of an ideal solution is inadequate to explain the absorption by the ground material.

Assuming that all of the absorption occurs in but one phase of the wheat, the values of the distribution coefficient a (assuming $b=1$) are plotted in figure 2, and indicate a heat of absorption of 8300 calories per mole of carbon tetrachloride, a figure which hardly differs beyond the experimental error from the heat of condensation of pure carbon tetrachloride, 7700 calories per mole.

Nevertheless, it seems reasonable to assume that the same absorption which took place in the unground wheat occurred also in the ground wheat. The vapor must naturally be in equilibrium with each phase of the wheat in which absorption has occurred. For each vapor concentration of table 3 the amount of carbon tetrachloride which the wheat would have absorbed if unground was calculated from equation (1) and subtracted from the total absorbed amount, n_2 in table 3, to give the extra absorption n_2' recorded in the table.

Those values of "extra" absorption by the ground wheat are plotted in figure 3. Again the curve must go through the origin, and with the exception of two points, the experimental values do not deviate from a straight line beyond the experimental error. The type of this "extra" absorption is thus not clearly indicated. As mentioned above, typical surface absorption would lead to a curve more or less concave downward, and such absorption may be a contributing factor here. On the other hand an approximately linear curve would probably result if this extra carbon tetrachloride were being absorbed by some phase of the ground wheat to form a solution so far from ideal that the mole percentage of carbon tetrachloride in solution was far less than the percentage saturation of the vapor.

If this is the explanation, then the process of grinding has exposed in the wheat a second solvent either much more abundant or else of lower molecular weight than the fat which caused the absorption before grinding. (It may be noted that the amount of water present in wheat is entirely inadequate to explain the extent of this "extra" absorption.) An attempt to prove that the extra absorption of figure 3 is accounted for by a process of solution, by extending the study to higher concentrations, might lead to extensive surface absorption if the solubility was overstepped and a separation into two phases was thus brought about.

Rates of Absorption.—Table 4 gives the percentage of the equilibrium amount of absorbed carbon tetrachloride which was absorbed by the wheat during the first day, as well as the time required for the absorption of ninety per cent of the equilibrium amount. These values were estimated graphically from the data taken at various times during the course of the absorption. As in tables 1 and 2, each figure in the third column is the average for two separate determinations, and these figures are given in the order of decreasing equilibrium concentrations of carbon tetrachloride.

Some generalizations appear from table 4. The very slow rates of absorption in the case of the unground grain, as compared with the ground grain, were probably caused by slow diffusion of dissolved carbon tetrachloride into the interior of the kernel. Although an increased rate is expected at the higher temperatures, it is evident that this effect is almost masked by the accidental variations in the data.

It will be noted, in the case of the unground grain, that prior extraction considerably increased the rate of absorption.

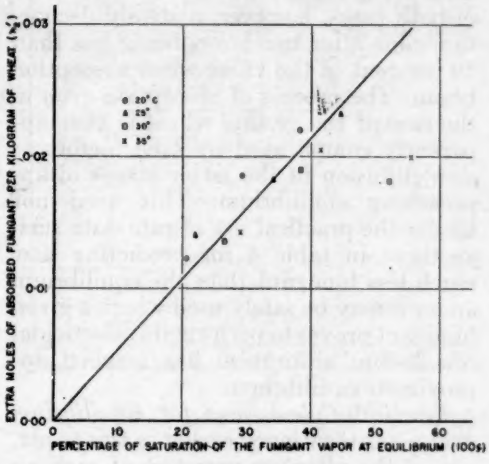

FIG. 3.—A comparison of the values of n_2' and f from table 3.

Perhaps the grain was made more porous by the extraction, since a removal of fats near the surface of the grain would be expected to slow the net rate. On the other hand, data obtained on ground grain (not recorded in this paper) definitely indicate that prior extraction in that case considerably slowed at least the last stages of the absorption.

Table 4.—Progress of absorption with time.

DESCRIPTION OF WHEAT	TEMPERATURE (°C.)	PER CENT OF TOTAL ABSORPTION OCCURRING THE FIRST DAY (FOR THE DIFFERENT CONCENTRATIONS USED)				TIME REQUIRED FOR 90 PER CENT OF TOTAL ABSORPTION (AVERAGE)
Unground; 8 per cent moisture	20	59	53	47	52	10 days
	25	50	40	25	11	14 days
	30	66	62	55	42	7 days
	35	66	53	57	65	9 days
Unground; 16 per cent moisture	35	66	66	47	30	11 days
Unground; extracted 8 per cent moisture	25	88	88	70	79	4 days
Ground; 8 per cent moisture	20	98	98	97		2 hours
	25	97	99	100		3 hours
	30	99	99	100		1 hour
	35	98	98	97		1 hour

If the process of absorption were very simple, it should be possible to assume the rate to be proportional to the distance from equilibrium and to calculate a "specific rate" which remained constant as absorption continued. The specific rate so calculated for the two extreme concentrations for ground wheat at 25° C. showed in both cases, however, a steady decline, the value after two hours being less than 10 per cent of the value when absorption began. The process of absorption even in the case of the ground wheat is thus apparently complicated by such factors as slow diffusion in the latter stages of approaching equilibrium. This need not hinder the practical use of rate data such as those in table 4 for predicting how much less fumigant than the equilibrium amount may be safely used where a given fumigant proves to perform its insecticidal role before absorption has reached approximate equilibrium.

Practical Calculations for Equilibrium Data.—As mentioned earlier in this paper, one of the ultimate purposes of such an investigation as this is to enable an estimation of the amount of a given fumigant to introduce into a quantity of wheat in order to insure a predetermined minimum concentration of fumigant vapor throughout a grain mass. It will now be demonstrated, using the data for carbon tetrachloride, how such a calculation can conveniently be made.

In terms of the symbols defined earlier in this paper, the equation giving the total amount of fumigant to be introduced is:

$$\frac{N}{V} = (Mc) \cdot \left(1-\frac{FD'}{D}\right) + (n_2 M) \cdot (FD') \qquad (3)$$

Total grams of fumigant introduced per liter of container	Grams of fumigant remaining in gas phase per liter of gas	Liters of gas phase per liter of container	Grams of fumigant absorbed per kilogram of wheat	Kilograms of wheat per liter of container
	Grams of fumigant remaining in gas phase, per liter of container		Grams of fumigant absorbed by wheat per liter of container	

Equation (3) is independent of any assumed law of absorption by the wheat, but can be made more practical when the distribution law for the case at hand is known. For example, solving equation (1) for n_2 and substituting into equation (3), and replacing f by c/c_0, an equation applicable to carbon tetrachloride and unground wheat is obtained:

$$\frac{N}{V} = \left(1-\frac{FD'}{D}+\frac{FD'\,n_1}{c_0-c}\right)(Mc). \qquad (4)$$

Or by substituting in equation (3) for n_2 from equation (2) (setting $b=1$), an equation applicable to carbon tetrachloride and ground wheat is obtained.

$$\frac{N}{V} = \left(1-\frac{FD'}{D}+FD'\,a\right)(Mc). \qquad (5)$$

For a may be substituted the approximate expression $205.6-0.64\ T$, and for the quantity (Mc) in either equation (4) or (5) is to be substituted the desired grams of gaseous fumigant per liter of gas phase.

The true density D of the wheat used in the present investigation was found by immersion in toluene to be 1.439 grams per cc. in close agreement with values previously published for other samples of wheat. D', the grams of wheat which fill one cc. without tamping, was found to have an average value of 0.804 for cleaned wheat and 0.800 for uncleaned wheat. (In bins the height of wheat is so much greater than in these laboratory determinations that considerable tamping of part of the grain by the weight of the grain above may occur.) The definition of the symbol F used in this paper similarly represents the fraction of the container filled by wheat without tamping.

Figure 4 illustrates for several extreme cases the use of equation (4) for carbon tetrachloride and unground whole wheat. The value of n_1 was taken as 0.022, the average from table 1.

SUMMARY.—(1) The investigations reported in this paper were undertaken for the purpose of obtaining data on the spe-

cific manner in which carbon tetrachloride is absorbed by whole wheat as well as by some specially prepared samples, and also to devise a practical method for calculating the amount of fumigant which must be added to a known quantity of grain in order to insure a predetermined minimum concentration of the fumigant.

(2) A manometric method is described whereby the quantity and the rate of uptake of a fumigant can be accurately measured.

(3) Sample calculations to be used with the method are presented.

(4) The observed extent of absorption of carbon tetrachloride by unground whole wheat was explained by assuming the formation of an ideal solution in the wheat oils, and the application of Raoults' Law to other types of fumigants is discussed. Calculations from the absorption data with carbon tetrachloride indicated the effective solvent to constitute about 2 per cent of the weight of the wheat, in very good agreement with the reported fat content of this type of wheat.

(5) Samples of the same wheat, if previously ground, were found to absorb additional amounts of carbon tetrachloride evidently not held in ideal solution.

(6) From the temperature coefficients of the absorption by both unground and ground wheat the heat of absorption was calculated and found to be close to the heat of condensation of carbon tetrachloride vapor to pure liquid.

(7) Virtual absorption equilibrium was attained within one day in the case of the ground wheat, but required almost three weeks in the case of unground wheat.

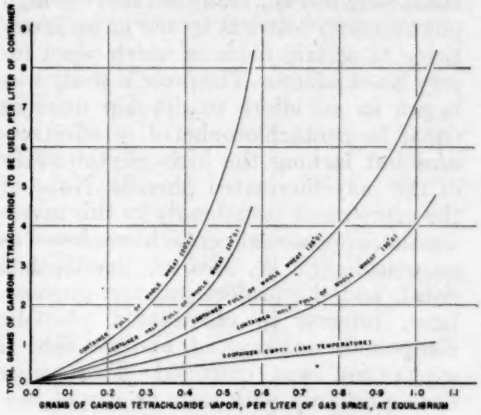

FIG. 4.—An illustration of the use of equation (4) for CCl_4 and unground wheat.

(8) The equilibrium data are used to illustrate the construction of practical graphs showing how much fumigant must be introduced under specified conditions in order to establish any desired equilibrium concentration of gaseous fumigant. —12-14-46.

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Toxicity of Some Chlorinated Phenol Derivatives

CARL J. WEINMAN[1] and GEORGE C. DECKER[2,3]

The toxicity of pentachlorophenol to various insects is well known (Ginsburg, 1935; Siegler *et al.*, 1939) but its very high phytotoxicity restricts its use as an insecticide to certain fields in which plant injury is not a factor. The present study was begun in an effort to develop ovicides equal to pentachlorophenol in effectiveness but lacking the high phytotoxicity of the polychlorinated phenols. None of the compounds tested early in this investigation approached pentachlorophenol as an ovicide (C. W. Kearns, unpublished data), and the project was not pursued. later, interest in chlorinated phenolic compounds was revived, and the field of exploration was extended. This paper deals primarily with tests on carpet beetles, houseflies, and red spiders.

It was not the purpose of this invesigation to determine accurately the toxicity of each material at various dosage levels. To indicate the relationship between chemical structure and toxicity to both plants and arthropods, if such a relationship exists, requires only the evaluation of the relative toxic limits of the compounds. A more practical consideration was the hope that the modifications of the pentachlorophenol molecule would result in one or more compounds which would retain the high toxicity to arthropods but not the objectionable properties of the parent compound.

TESTS ON HOUSEFLIES.—For comparative evaluation of compounds in this study, the method developed by Kearns (1943) was used. This method is particularly valuable for preliminary screening work, since non-effective materials can be eliminated quickly and because it affords a means of evaluating toxicity even when a compound exhibits little or no knockdown effect.

The houseflies used in these experiments were reared according to the standard, Peet-Grady procedure. Most of the compounds were formulated in solutions of benzene and Deobase oil for these tests. All of the materials were tested at 10 per cent concentrations (or at saturation, when the compounds were less than 10 per cent soluble), and those which gave good kills were checked again at lower dosages. Results of the housefly tests and the experiments on carpet beetle larvae are summarized in table 1.

Carpet Beetle Tests.—Larvae of the black carpet beetle, *Attagenus piceus* Oliv., were used for these experiments, which were run according to the tentative N.A.I.D.M.[4] method (Fletcher, 1943), except that visual damage, as determined by examination under a binocular microscope, was used as the criterion of effectiveness of the compounds. White, pure wool flannel cloth was treated by immersion in 10, 5, and 1 per cent (by weight) solutions of the test compounds in benzene, acetone, Oleum Spirits, or other suitable solvent.

In table 1, the compounds are compared by rating them as to toxicity and repellency to black carpet beetle larvae and by estimating the duration of their effectiveness, based on continual reinfestations with fresh larvae during the periods of test. For an additional indication of persistency, replicate tests of some of the less volatile materials were exposed in an oven at 60° C. for various periods to accelerate the decrease in effectiveness due to aging. This heat-treatment technique is valuable for comparing materials, but it does not enable one to make any exact predictions of the duration of effectiveness under ordinary room conditions. However, most treatments which will remain effective for six months to a year at room temperature are almost entirely ineffective after 24 to 48 hours of heat treating at 60° C.

Red Spider Tests.—The common red spider, *Tetranychus telarius* Linn., living on Better Times roses, was used for all of the mite tests. Excised leaves were sprayed with solutions of the compounds dissolved in 65 per cent acetone and 35 per cent distilled water plus *Santomerse D*

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[3] This investigation was sponsored by the Monsanto Chemical Company of St. Louis, Missouri, who prepared and supplied all of the compounds for these tests. The authors acknowledge also the interest of the late Professor W. P. Flint, under whose direction some of this work was carried out.

[4] National Association of Insecticide and Disinfectant Manufacturers.

Table 1.—Tests of chlorinated phenol derivatives.

Compound		Kearns-Chamber Tests on Houseflies			Toxicity of Treated Wool to Larvae of the Black Carpet Beetle 4 = most toxic or most repellent 0 = nontoxic or nonrepellent		
		Conc. in % by wt.	Ave. % dead 24 hrs.	Ave. % moribund 24 hrs.	Toxicity	Repellency	Persistency of 5% treatment
Pentachlorophenol	C_5Cl_5OH	5.0	100	0			
		2.5	74	0			
		1.0	18	1	4	2	>18 months
Alkyl Ethers of Pentachlorophenol							
Methyl	$C_5Cl_5OCH_3$	10	0	0	1	0	
Propyl	$C_5Cl_5OC_3H_7$	10	20	0	4	3	9 months
n-Butyl	$C_5Cl_5OC_4H_9$	10	11	1	4	4	12 months
Mixed primary amyl	$C_5Cl_5OC_5H_{11}$	10	19	0	4	4	15 months
n-Hexyl	$C_5Cl_5OC_6H_{13}$	10	2	0	2	3	15 months
n-Dodecyl	$C_5Cl_5OC_{12}H_{25}$	10	0	0	1	2	
Other Ethers of Chlorinated Phenols							
Allyl pentachlorophenyl ether	$C_5Cl_5OCH_2CH{:}CH_2$	5.0	100	0			
		2.5	51	12			
		1.0	4	0	4	2	>18 months
Tetrahydrofurfuryl pentachlorophenyl ether	$C_5Cl_5OCH_2(C_4H_7O)$	10	13	0	2	1	
2,4-Dinitrophenyl pentachlorophenyl ether	$C_5Cl_5OC_6H_3(NO_2)_2$	10	0	0	0	0	
Benzyl pentachlorophenyl ether	$C_5Cl_5OCH_2C_6H_5$	5	0	0	0	0	
2,4,6-Trichlorobenzyl pentachlorophenyl ether	$C_5Cl_5OCH_2C_6H_2Cl_3$	8	7	0	0	0	
2,4,6-Trichlorobenzyl 2,3,4,6-tetrachlorophenyl ether	$C_6HCl_4OCH_2C_6H_2Cl_3$	10	1	0	0	0	
2,4,6-Trichlorobenzyl 2,4,5-trichlorophenyl ether	$C_6H_2Cl_4OCH_2C_6H_2Cl_3$	10	1	0	0	1	
Chlorinated Phenoxyacetates							
Ethyl pentachlorophenoxyacetate	$C_5Cl_5OCH_2COOC_2H_5$	10	2	0	0	1	
2-Pentachlorophenoxyethyl acetate	$C_5Cl_5OCH_2CH_2COCCH_3$	10	46	10	3	2	18 months
Butyl pentachlorophenoxyacetate	$C_5Cl_5OCH_2COOC_4H_9$	10	45	2	1	1	
Ethyl tetrachlorophenoxyacetate	$C_6HCl_4OCH_2COOC_2H_5$	10	45	3	3	3	18 months
Butyl tetrachlorophenexyacetate	$C_6HCl_4OCH_2COOC_4H_9$	10	85	0	3	3	18 mont's
1-Pentachlorophenoxy-2,3-propane diacetate	$C_5Cl_5OCH_2CHOOCCH_3$-CH_2OOCCH_3	10	51	5	2	2	
Miscellaneous Chlorinated Phenol Derivatives							
Benzyl tetrachlorophenol	$C_6H_5CH_2C_6Cl_4OH$	10	94	0	3	3	18 months
Pentachlorophenoxyacetic acid	$C_5Cl_5OCH_2COOH$	10	2	0	1	3	
2-Pentachlorophenoxyethanol	$C_5Cl_5OCH_2CH_2OH$	10	72	1	3	2	6 months
2-(2',4'-Dichlorophenoxy)-ethanol	$C_6H_3Cl_2OCH_2CH_2OH$	10	95	0			
		5	60	1	2	2	
1-Pentachlorophenoxy-2,3-propanediol	$C_5Cl_5OCH_2CHOHCH_2OH$	10	0	0	2	3	
Controls							
Benzene		100	0	0	0	0	
Benzene-Deobase, 50-50		—	2	0	—	—	
Deobase		100	0	0	0	0	
Miscellaneous solvents		—	—	—	0	0	

(sodium decylbenzene sulfonate) at 1 to 3000 as a wetting agent. After having been sprayed, the leaves were kept fresh for 24–48 hours by placing the stems in capillary tubes filled with water, according to the method described by Kearns (1938).

Table 2 shows the results of tests based on counts made 24 hours after spraying. The per cent mortality refers only to large mobile stages. The effectiveness of test solutions against eggs and resting stages was measured by the relative numbers of live larvae and individuals newly emerged from resting stages on the sprayed leaves.

Phytotoxicity Tests.—The toxicity of the compounds to plants was determined by spraying miscellaneous potted plants with acetone-water-Santomerse solutions of the compounds. Most of the effective materials were checked also on roses growing in benches, by spraying the plants with emulsions of the compounds. The relative toxicity of these chemicals to plants is recorded also in table 2.

DISCUSSION.—Pentachlorophenol is a white, crystalline solid, and so is its methyl ether. The propyl ether derivative is a waxy solid, and the higher alkyl ethers of pentachlorophenol are white or slightly yellowish, oily liquids. All of the other compounds are crystalline solids except tetrahydrofurfuryl pentachloro-

Table 2.—Phytotoxicity and toxicity to greenhouse red spider on excised rose leaves.

Compound	Ave. Mortality, Mobile Stages at 1–500	Greatest Dilution Giving 90%–100% Mortality	Effectiveness on Eggs and Resting Stages	Relative Phyto-toxicity 4 = most toxic 0 = no toxicity
Pentachlorophenol	100	1–16,000	Excellent, 1–8,000	4
Alkyl Ethers of Pentachlorophenol				
Methyl	100	1–1,000	Good, 1–1,000	0
Propyl	96	1–500	Excellent, 1–500	0
n-Butyl	94	1–1,000	Good, 1–1,000	1
Mixed primary amyl	97	1–1,000	Good, 1–1,000	1
n-Hexyl	100	1–1,000	Excellent, 1–1,000	2
n-Dodecyl	66		No control	2
Other Ethers of Chlorinated Phenols				
Allyl pentachlorophenyl ether	100	1–4,000	Excellent, 1–4,000	4
Tetrahydrofurfuryl pentachlorophenyl ether	100	1–1,000	Excellent, 1–1,000	1
2,4-Dinitrophenyl pentachlorophenyl ether	26		No control	0
Benzyl pentachlorophenyl ether	24		No control	0
2,4,6-Trichlorobenzyl pentachlorophenyl ether	60		No control	0
2,4,6-Trichlorobenzyl 2,3,4,6-tetrachlorophenyl ether	14		No control	0
2,4,6-Trichlorobenzyl 2,4,5-trichlorophenyl ether	33		No control	0
Chlorinated Phenoxyacetates				
Ethyl pentachlorophenoxyacetate	35		No control	0
2-Pentachlorophenoxyethyl acetate	100	1–2,000	Excellent, 1–2,000	3
Butyl pentachlorophenoxyacetate	100	1–4,000	Excellent, 1–2,000	3
Ethyl tetrachlorophenoxyacetate	100	1–2,000	Excellent, 1–2,000	3
Butyl tetrachlorophenoxyacetate	100	1–8,000	Excellent, 1–4,000	4
1-Pentachlorophenoxy-2,3-propane diacetate	100	1–1,000	Good, 1–1,000	3
Miscellaneous Chlorinated Phenol Derivatives				
Benzyl tetrachlorophenol	100	1–8,000	Excellent, 1–4,000	4
Pentachlorophenoxyacetic acid	0		No control	0
2-Pentachlorophenoxyethanol	100	1–4,000	Excellent, 1–4,000	3
2-(2′,4′-Dichlorophenoxy)-ethanol	85		Poor, 1–500	3
1-Pentachlorophenoxy-2,3-propanediol	99	1–500	Poor, 1–500	3
Control				
Acetone—65%, water—35% plus Santomerse D at 1–3,000	5.6		No control	0

phenyl ether, which is a waxy solid. These differences in physical properties may have their effects on toxicity to arthropods and plants. All of the solid ethers except allyl, for example, have a very low phytotoxicity. The butyl and amyl ethers show some toxicity to plants at concentrations within their effective range (on red spiders) and the higher alkyl ethers are very phytotoxic. Part of this toxicity is very likely a function of the relatively non volatile, oily nature of these longer-chain alkyl ethers. Similarly, oily liquids, almost without respect to chemical composition, show some toxicity to red spiders and repellency to carpet beetles. It must be kept in mind, therefore, in a discussion of toxicity that the physical properties of the compounds concerned may be as important as their chemical composition.

None of the compounds tested is quite as toxic as pentachlorophenol to house flies. Solutions of the second most toxic material, allyl ether, when sprayed into a room are almost as irritating to man as are solution of the free phenol.

In spite of its very high toxicity and repellency to black carpet beetle larvae, pentachlorophenol holds no promise as a mothproofing agent. Its irritating properties are a serious disadvantage, and it has

a tendency to stain white wool. The allyl ether of pentachlorophenol has the same disadvantages. However, until the advent of DDT, the propyl, butyl, and amyl ethers were considered promising mothproofing agents. These compounds have almost no odor, do not stain wool, and are of outstanding toxicity. One-half to five per cent treatments of all three compounds kill carpet beetle larvae more quickly than similar concentration of DDT. Their threshold of toxicity is lower than their threshold of repellency, since treatments lower than one per cent are toxic to the larvae but do not prevent considerable feeding. The butyl ether, at least, is also highly toxic and repellent to clothes moth larvae.

Many of the pentachlorophenol ethers have been tested as stomch poisons on a number of insects. In general, these tests have indicated a fair to very high toxicity for the alkyl ethers in the range of C_3–C_5 on most Coleopterous species but only moderate to very low toxicity to most Lepidopterous insects. As a 5 per cent dust, the butyl ether, for example, was at least as toxic as a 10 per cent lead-arsenate dust on clover weevils, blister beetles, and Colorado potato beetles. The same material gave poorer results than lead arsenate on larvae of the silkworm cabbage arctiid, corn borer, and codling moth. The methyl ether, however, was more toxic than lead arsenate to newly hatched codling moth larvae, but the residue on the apples lost its toxicity rapidly after a few days.

Pentachlorophenol has an outstanding toxicity to red spiders. Field applications of this compound at 1 to 15,000 (dissolved in pine oil and emulsified with *Duponol OS*, (N,N-diethyl-cyclohexylamine alkyl sulfate)) gave adequate control of spiders but caused moderate injury on roses and severe injury on beans. Butyl tetrachlorophenoxyacetate and benzyl tetrachlorophenol were the most toxic of the chlorinated phenol derivatives, but they are nearly as toxic to plants as is pentachlorophenol. The allyl ether of pentachlorophenol also rivals the free phenol in herbicidal properties. None of the chlorinated phenoxyacetates and phenoxyethanols appears to offer a dependable margin of safety between toxicity to spiders and toxicity to plants.

Among the ethers of pentachlorophenol, methyl, propyl, butyl, amyl, and tetrahydrofurfuryl gave adequate kills of spiders at concentrations lower than their thresholds of toxicity to plants. Of these compounds, the methyl ether offers the greatest margin of safety. This material gave no injury when applied even at 1 to 100 on potted mum and stock plants, and no injury has been observed on roses, beans, potatoes, raspberries, or peach seedlings sprayed or dusted with the methyl ether at concentrations effective against spiders.

A number of these chlorinated phenol derivatives give evidence of having a residual effect on spiders. Excised, uninfested rose leaves were sprayed with the methyl ether at 1 to 500 in acetone-water-Santomerse D solution, and spiders were allowed to crawl from unsprayed to the sprayed leaves. After 24 hours, there was a 73 per cent kill of mobile stages, and after four days, 98 per cent of the mobile stages were dead. When half a house of Better Times roses in a large commercial range was sprayed with the methyl ether at 1 to 1000, formulated with *AR-50* (alkylated naphthalenes), pine oil, and *Duponol OS*, the kill of mobile stages in 24 hours was 93.1 per cent; in 48 hours, 95.7 per cent, and after one week, 97.1 per cent. Records on larvae and mites newly emerged from resting stages indicated that most of those which were able to emerge after the spraying died within 24 hours.

Methyl pentachlorophenyl ether is rather difficult to formulate as an emulsion because of its low solubility in all of the solvents commonly used in plant sprays. Most of the attempts to apply emulsions of this compound resulted in a partial crystalization of the compound in the spray tank. The deposition of crystals on the leaves, however, greatly increases the residual kill of spiders.

Because the methyl ether is a white powder, its use as a dust or water suspension results in a residue rather objectionable on the foliage of greenhouse crops. Although no such objection would be raised to residues on most agricultural crops, it appears that the compound must be used at concentrations considerably higher than 1 to 1000 when it is applied as a water suspension. In one field test, application of 1.6 lbs. per 100 gallons gave only 80 per cent kill of mobile

stages and effected almost no control of eggs or resting stages. Since methyl ether has never been prepared in commercial quantities, it is impossible to say whether its cost will be low enough to permit its practical use on agricultural crops.

In view of the increasing mite populations on agricultural crops resulting from the use of DDT, it seems to the authors that further studies on certain of the alkyl ethers of pentachlorophenol and further exploration in the field of chlorinated phenol derivatives for mite control is highly desirable.

CHEMICAL STRUCTURE AND TOXICITY.—The profound change in chemical and physical properties effected by the replacement of the H in pentachlorophenol with a CH_3 group gave rise to the hope that similar replacements with other groups would lead to some interesting and definite correlations among chemical structure, toxicity to insects, and toxicity to plants. Some progressive effects in toxicity to arthropods can be observed as the length of the chain in the alkyl ethers is increased from methyl to butyl or amyl, and there is clearly a marked decrease in toxicity from amyl to hexyl and especially from hexyl to dodecyl. Correlations in toxicity to plants among these compounds is obscured by their differences in physical properties. It also seems fairly safe to conclude that the formation of aryl and aralkyl ethers of pentachlorophenol results in almost complete loss of toxicity to both arthropods and plants. This appears to hold even when the aryl or aralkyl group is nitrated or chlorinated.

The relationship of structure to toxicity among the alcohol, acetic acid, and acetic ester ethers of pentachlorophenol, however, is not well defined. In general, these compounds show a high toxicity to both arthropods and plants, but exceptions to this generalization make it difficult to draw conclusions. Both pentachlorophenoxyacetic acid and its ethyl ester are almost non toxic. The isomeric ester, 2-pentachlorophenoxyethyl acetate is very toxic, and so is the ethyl ester of tetrachlorophenoxyacetic acid. It is impossible, therefore, to ascribe toxicity either to the nature of the substituted group or to its position in the molecule.

SUMMARY AND CONCLUSIONS.—Pentachlorophenol and twenty-four derivatives of chlorinated phenols were tested against houseflies, black carpet beetle larvae, and the common red spider. Phytotoxicity studies were made also on each compound.

None of the chlorinated phenol derivatives is equal to pentachlorophenol in toxicity to houseflies.

Propyl, butyl, and amyl ethers of pentachlorophenol are equal to or better than pentachlorophenol in toxicity and repellency to black carpet beetle larvae. These compounds lack the odor, color, and irritating properties of the parent phenol.

Pentachlorophenol is effective against the common red spider on roses at a dilution of 1–16,000 but is still phytotoxic at that concentration. Other compounds which approach pentachlorophenol in toxicity to spiders are also highly toxic to plants.

Methyl, propyl, butyl, amyl, and tetrahydrofurfuryl pentachlorophenyl ethers are effective against mites at concentrations below their thresholds of phytotoxicity. Of these materials, the methyl ether offers the greatest margin of safety.

The toxicity of the alkyl ethers of pentachlorophenol increases from methyl to amyl and decreases from amyl to dodecyl. Aryl and aralkyl ethers are practically non toxic. Other relationships between chemical structure and toxicity are not apparent.—11-29-46.

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A Chlorinated Bicyclic Terpene Used to Control Certain Fruit and Vegetable Insects[1]

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The chlorinated bicyclic terpene, now designated *Toxaphene*[2] is an insecticide developed cooperatively by Hercules Powder Company chemists and University of Delaware entomologists under a long-term investigational program. This synthetic has the approximate empirical formula $C_{10}H_{10}Cl_8$. On the basis of physical and biological properties, it is the most promising toxicant discovered in explorations involving hundreds of organic compounds. It can be formulated readily into oil-soluble, water-dispersible, wettable-powder, and dust concentrate forms. Since terpenes are available in large quantities, an adequate supply of this product is assured for commercial use.

Details of the research which led to the discovery and development of *Toxaphene* form the subject matter of a Delaware Station technical bulletin which is near completion.

The first published report on *Toxaphene* by Stearns *et al.* (1946), dealt with preliminary laboratory and field tests in which this compound competed successfully with DDT as a mosquito larvicide. That release was made in order to expedite evaluation of its possibilities by other workers to whom experimental samples would be made available upon request.

These conclusions, with respect to its effectiveness against culicines in 1945, are supported by the findings of Deonier *et al.* (1946), in which *Toxaphene* received a superior rating in tests utilizing anopheline larvae. Subsequently, Bishopp (1946) commented briefly and favorably upon its performance in recent work with a number of pests, some affecting man and animals and others causing damage to crops. Stearns (1947) has reported, also, on results against certain household insects.

In Delaware, during 1946, an effort was made to establish, in so far as possible in a single season, the value of this new toxicant when used alone and in combination with other insecticides and fungicides against certain locally-important fruit and vegetable insects. Both DDT, used at the same dosages, and the recognized controls for the several species concerned, were selected as criteria for rating the efficiency of *Toxaphene*. Results, presented very briefly under appropriate headings, are as follows:

Compatability.—As a 25 per cent wettable powder, *Toxaphene* was compatible with sulfurs, *Fermate*, bordeaux mixtures, *Yellow Cuprocide*, copper *Compound A*, lead arsenate, calcium arsenate, summer oils, and nicotine sulfate. *Pyrax ABB* proved to be a satisfactory diluent for the 50 per cent dust concentrate. The 50 per cent water-dispersible formulation was not used in combination with other materials. No plants were treated with the oil-soluble concentrate, alone or otherwise.

Phytotoxicity.—The 25 per cent wettable powder, at rates of 1 and 2 pounds per 100 gallons, produced no injury on string beans (Bountiful) or on lima beans (Fordhook) and, at the rate of 1 pound per 100 gallons, produced no injury on apples (Grimes Golden, Red Delicious, and Starking Delicious), on grapes (Concord and Delaware), and on peaches (Golden East, Summercrest, and Triogem).

At the rates of 1 and 2 pounds per 100 gallons, cucumbers (National Pickling) and cantaloupes (Jumbo Hale's Best) showed severe chlorosis, followed by necrosis, the plants becoming badly dwarfed or being completely destroyed. At the rate of 1 pound per 100 gallons, potatoes (Dakota Red and Irish Cobbler) showed a slight yellowing of the terminal leaflets, a condition which disappeared, however, within 2 weeks after the last spray application.

The 50 per cent water-dispersible formulation, used at the rate of 1 pound per 100 gallons, produced no injury on the apple, grape, and peach varieties previously listed but, at this rate, caused severe chlorosis in the case of the potato varieties mentioned above.

[1] Published as Miscellaneous Paper No. 16, with the approval of the Director of the Delaware Agricultural Experiment Station. Publication 206 and Scientific Article 130 of the Department of Entomology, November 14, 1946.

[2] First designated as *Hercules Synthetic 3956*.

When used as a dust, *Toxaphene* (2.5 and 5 per cent concentrations in *Pyrax ABB*) produced no injury on the string and lima bean varieties under test. The cucumber and cantaloupe varieties, however, showed severe chlorosis, as before described, and squash (Boston Marrow) was likewise adversely affected.

FUNGICIDAL ACTION.—This toxicant was subjected to current, popular, fungicidal-screening tests[1] by the test tube dilution method on two organisms—*Sclerotinia fructicola* (Wint.) Rehm and *Macrosporium sarcinaeforme* Cav.—commonly used for this purpose. The L.D. 50 is higher than 500 ppm. Therefore, the compound would appear to have practically no fungicidal property.

CODLING MOTH.—*Toxaphene* and DDT were compared for codling moth control in a block of 19-year-old Red Delicious apples. Two schedules were tested: in the first, each of these toxicants was used alone; in the second, each was used at a reduced dosage and in combination with lead arsenate and summer oil. Treatments were replicated four times on nine-tree plots. Seven applications (a petal fall and six cover sprays) were made with a 500-gallon speed sprayer (rate, 15 gallons per tree) on the following dates: April 29, May 16, May 29, June 11, June 25, July 11, and July 23.

Lead arsenate (3 pounds per 100 gallons) was used in the petal-fall spray in both schedules. Subsequently, in the first schedule, *Toxaphene* or DDT was included at the rates of 1 pound in the first- and fourth-cover sprays and 0.75 pound in the second-, third-, and fifth-cover sprays. Subsequently, in the second schedule, *Toxaphene* or DDT was included at the rate of 0.5 pound in all cover sprays; lead arsenate (3 pounds), in the first- and fourth-cover sprays; and summer oil—83 per cent (3 quarts), in all cover sprays except the first. In the first schedule, flotation sulfur paste—45 per cent (12 pounds) was the fungicide in the petal-fall spray and in the first-cover spray (8 pounds), while *Fermate* (1.5 pounds) was used in the second-cover spray. In the second schedule, *Fermate* (1.5 pounds) was the fungicide in the petal-fall, and first- and second-cover sprays. In both schedules, bordeaux (0.5–3–100) was included in the third-, fifth-, and sixth-cover sprays and (1–3–100) in the fourth-cover spray.

With DDT, the first schedule produced a crop with 95.5 per cent of the apples uninjured by codling moth; the second schedule, 99 per cent. In both cases, the variation in replicates did not exceed one per cent.

With *Toxaphene*, the comparable percentages were 75 and 85. In the first case, the percentage for one replicate (50) was 39 below the average for the other three. In the second case, two replicates agreed closely, averaging 77 per cent, and the other two, likewise agreeing closely, averaged 92 per cent. Such variation can be expected in the early use of any new compound before its production has been standardized.

The established lead arsenate-oil-nicotine program produced 93 per cent clean fruit.

Under both test schedules, the residue situation with these toxicants was satisfactory. The red mite infestation was uniformly light (fewer than five mites per leaf) throughout the experimental block. However, the population was consistently greater on the DDT-treated trees.

CURCULIO AND ORIENTAL FRUIT MOTH.—The established lead arsenate program and variations therefrom utilizing *Toxaphene* and DDT were compared for curculio and Oriental fruit moth control in a block of three-year-old Summercrest peaches. Treatments were replicated six times on 16-tree plots. Either three or five applications (depending upon the program involved) were made with a 300-gallon *Hardie* sprayer equipped with two, four-nozzle brooms (rate, 3 gallons per tree) on the following dates: April 9, April 30, May 17, July 3, and July 15.

The established program included lead arsenate (2 pounds), lime (5 pounds), zinc sulfate (2.75 pounds), and magnetic sulfur paste—70 per cent (7.5 pounds per 100 gallons) in the petal-fall, first-, and second-cover sprays.

When either *Toxaphene* or DDT was substituted in the applications just mentioned, it was used at the rate of 1 pound; lime and zinc sulfate were omitted.

When two supplemental *Toxaphene* or DDT applications were made in July, they were again used at the 1-pound rate and in combination with 1 quart of sum-

[1] By Department of Plant Pathology, University of Delaware.

mer oil—83 per cent; sulfur was included as indicated above.

The extent of curculio infestation in dropped peaches was uniformly heavy and wholly unaffected by the six treatments under test.

The substitution of *Toxaphene* or DDT for lead arsenate in the usual, three, early-season peach sprays did not influence twig injury by Oriental fruit moth or the activities of the parasitic enemies of the moth.

The results of the two supplemental applications in July were much the same for *Toxaphene* and DDT. With *Toxaphene*, twig injury (second brood) was reduced about 23 per cent and parasitism about 33 per cent. With DDT, the comparable percentages were 44 and 27.

MEXICAN BEAN BEETLE.—String beans of the Bountiful variety and lima beans of the Fordhook variety were dusted and sprayed with *Toxaphene* and DDT for protection against Mexican bean beetle attack. Rotenone, the usual control, served as the check. Treatments were replicated three times on five-row, 0.01 acre plots.

Both of these varieties were affected by but a single brood of this insect. Applications were started when early-instar larvae became numerous, and were continued until hatching was over. On string beans, they were made on June 21 and 26 and on July 3; and on lima beans, on August 9, 14, and 22. Infestation data were collected 48 hours after each application. The population on string beans was relatively light—7 per untreated plant and, on lima beans, relatively heavy—31 per untreated plant. This range in abundance is reflected in the results. Harvest records for string beans were taken on July 22 and 29 and, for lima beans, on September 17 and 18. Further facts covering treatments and yields are summarized in table 1.

For practical purposes, the differences in yield among the several treatments cannot be considered significant. However, it is evident that the yields where either *Toxaphene* or DDT was used are equal to, or slightly greater than, those where rotenone was used. With the low population on string beans, treatments failed to produce a crop significantly greater than that harvested from unsprayed and undusted plants. With the substantially higher population on lima beans, the reverse was true.

Table 1.—Comparative yields for string and lima beans treated with Toxaphene, DDT, and rotenone dusts and sprays.

Treatments	Dosages	String Beans	Lima Beans	
		Tons per Acre		
		As harvested	As harvested	Shelled
Dusts—Pounds per acre		50	135	
Toxaphene	2.5%	2.9	6.1	1.8
DDT	2.5	2.9	5.2	1.4
Toxaphene	5.0	2.2	6.3	1.7
DDT	5.0	2.1	4.8	1.3
Rotenone	0.75	1.8	6.1	1.9
Sprays—Gallons per acre		100	160	
Toxaphene	1.0 lb.[1]	2.6	5.4	1.6
DDT	1.0	2.3	4.2	1.3
Toxaphene	2.0	2.9	5.6	1.5
DDT	2.0	1.7	6.3	1.8
Rotenone	0.15	2.4	3.9	1.2
Untreated check		2.2	2.4	0.8

[1] Per 100 gallons.

Neither *Toxaphene* nor rotenone caused any injury. DDT sprays and dusts, on the contrary, were responsible for a yellowing and slight stunting of the terminal growth on both varieties. This was apparent shortly after the first application in each instance; it was more extensive on string beans, and more pronounced at the higher concentrations; recovery was complete before harvest.

CUCUMBER BEETLES.—The experimental set-up on cucumbers (National Pickling variety) and on cantaloupes (Jumbo Hale's Best variety) was much the same as that described on beans, with these exceptions: only *Toxaphene* was used as a 5 per cent dust, and none of the test materials was applied as a spray on the cantaloupes. Treatments were replicated three times on three-row plots 33 feet long; 12-foot alleys separated the replicates.

The cucumbers were planted June 13. This was late; consequently, the yield was extremely light. Applications were made with hand equipment on June 24 and

Table 2.—Comparative yields for cucumbers and cantaloupes treated with Toxaphene, DDT, and rotenone dusts and sprays.

Treatments	Dosages	Number per Plot				
		Marketable Cucumbers	Vines	Marketable Cantaloupes[1]	Culls	Vines
Dusts—Pounds per acre		20 to 25		25 to 50		
Toxaphene	2.5%	103	78	22	25	47
DDT	2.5	170	74	54	16	48
Toxaphene	5.0	3	20	0	10	22
Rotenone	0.75	181	84	56	9	49
Sprays—Gallons per acre		75 to 125				
Toxaphene	1.0 lb.[2]	0	0			
DDT	1.0	143	69			
Toxaphene	2.0	0	0			
DDT	2.0	163	67			
Rotenone	0.15	160	69			
Untreated check		148	74	45	13	46

[1] Five inches and over.
[2] Per 100 gallons.

July 5 and 26. The amount of dust used per acre ranged from 20 pounds (first application) to 25 pounds (last application). The amount of spray varied, likewise, from 75 to 125 gallons per acre. The crop was harvested by 10 pickings from August 3 to 19, inclusive.

The cataloupes were planted on May 6. Applications were made with hand equipment on May 22 and 31, June 11 and 24, and July 5 and 26. The amount of dust used per acre ranged from 25 pounds (first application) to 50 pounds (last application). The crop was harvested by 12 pickings from August 6 to 22, inclusive.

In addition to the planned treatments in this experiment, the entire plantings of cucumbers and cantaloupes were sprayed with *Yellow Cuprocide* (1.8 pounds per 100 gallons) on July 15, 22, and 30 as a preventive measure against outbreaks of blight and downy mildew.

The populations of cucumber beetles (both the striped and the spotted species) were never high on either the cucumbers or the cantaloupes, and the yields in each case, under the several treatments, were never significantly greater than those recorded where dusts and sprays were not applied. The numbers of marketable cucumbers and cantaloupes from the DDT and the rotenone plots were essentially the same. As stated under the discussion heading, Phytotoxicity, *Toxaphene* caused severe injury to both cucumbers and cantaloupes. Yields were either negligible or no crop whatsoever matured. Reference: table 2.

POTATO LEAFHOPPER.—*Toxaphene* and DDT, alone and in combination with copper *Compound A*, were tested[1] on early Irish Cobbler potatoes for leafhopper control, with bordeaux as one check. Treatments were replicated four times on one-row plots of 25 plants each, with a single untreated row intervening; a 12-foot alley separated the four randomized blocks.

Five sprays were applied under 250 pounds pressure with a small, portable power sprayer on May 29, June 7, 17, and 26, and July 5. The amount of spray used was gradually increased in line with plant growth. Expressed on an acre basis, it ranged from 75 gallons (first application) to 150 gallons (last application). Six counts of the total leafhopper nymphs and adults on two leaves of seven leaflets each were made on June 19, 20, and 27, and July 1, 7, and 8. The percentage defoliation due to leafhoppers and early blight disease was estimated by observations on July 16 and 22. The plots were harvested on August 9. Treatments, with

[1] In cooperation with Dr. J. W. Heuberger, Associate Research Professor, Plant Pathology, University of Delaware.

leafhopper, defoliation, and yield data, are listed in table 3.

Table 3.—Comparative yields for potatoes treated with Toxaphane, DDT, and bordeaux sprays.

TREATMENTS	DOSAGES	LEAFHOPPERS[1]	DEFOLIATION PER CENT	BUSHELS PER ACRE[2]
Toxaphene	0.75 lb.[3]	6	62	209
DDT	0.75 lb.	3	31	292
Toxaphene and copper *Compound A*	0.75 lb. & 3½ lbs.	4	82	217
DDT and copper *Compound A*	0.75 lb. & 3½ lbs.	1	54	224
Bordeaux	6–3–100	2	72	208
Untreated check		10	90	230

[1] Total nymphs and adults on two leaves of seven leaflets each for six counts.
[2] Grades 1 and 2 combined; culls averaged one per cent of total yield.
[3] Per 100 gallons.

The absence of correlation in the data presented in table 3 is obvious. The untreated check, with a leafhopper population significantly higher than those recorded for the sprayed plots and with a substantially greater defoliation, outyielded all treatments except DDT alone. Production with *Toxaphene* alone and with the bordeaux check was the same. The yield for DDT and copper *Compound A* was 68 bushels less per acre than for DDT alone, yet with that combination the leafhopper population was the lowest noted. The relationship between population and yield, irrespective of treatments, seems worthy of study.

SUMMARY.—The insecticidal value of the chlorinated bicyclic terpene (*Hercules Synthetic* 3956) to which the name *Toxaphene* has been given was partially established in Delaware during 1946, through investigations involving several fruit and vegetable insects. This compound, tested as a yet unstandardized product, was rather highly effective against codling moth, without any resulting build-up in red mite population; it failed with curculio when used in two July applications, it decreased twig injury by second-brood Oriental fruit moth somewhat but, at the same time, was responsible for a reduction in the numbers of the parasites of this pest; it appeared equal to, or possibly slightly superior to, rotenone as a control for Mexican bean beetle; results with the striped and spotted cucumber beetles were inconclusive because of the small populations encountered; its status with respect to potato leafhopper will require further experimentation. As tested, *Toxaphene* showed practically no fungicidal action. The 25 per cent wettable powder proved to be compatible with most insecticides and fungicides used on fruits and vegetables. It caused no injury when applied on apples, grapes, peaches, and on string and lima beans, but produced severe chlorosis followed by necrosis on cucumbers and on cantaloupes and a slight yellowing of the terminal growth on potatoes. The 50 per cent water-dispersible formulation, although apparently safe on apples, grapes, and peaches, produced severe chlorosis on potatoes. When used as a dust, no difficulties were experienced on string and lima beans; cucumbers, cantaloupes, and squash, however, were adversely affected. The properties and the early performance of *Toxaphene* are in many respects similar to those displayed by DDT; as with that insecticide, continued and widespread research will be necessary to determine fully and accurately both its possibilities and its limitations.—11-21-46.

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An Analysis of Certain Factors Relating to Control of Grasshoppers with Some Chlorinated Hydrocarbon Insecticides[1,2]

CARL J. WEINMAN and GEORGE C. DECKER[3]

Field tests with sprays and dusts of chlordane,[4] DDT,[5] and benzene hexachloride against grasshoppers during the summer of 1946 indicated that chlordane and benzene hexachloride are outstanding in effectiveness against these pests (Weinman *et al.*, 1947). In order to evaluate more critically the action of these materials, small-plot tests in an alfalfa field and various greenhouse and laboratory tests were conducted. In addition to chlordane, DDT, and benzene hexachloride these investigations included *Toxaphene*,[6] which was not available in quantity sufficient for large-scale tests.

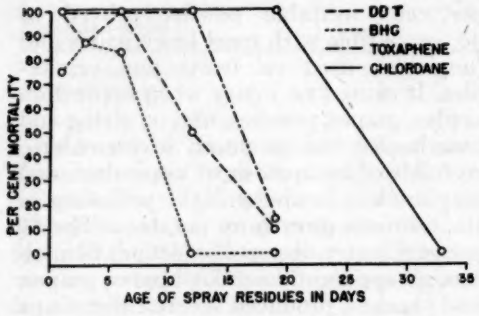

FIG. 1.—Persistency of the toxicity of residues of chlorinated hydrocarbons on plants. Potted bean plants sprayed with the four compounds at 1 to 500 in acetone-water solution and infested with adult *Melanoplus differentialis* at various dates after spraying. Mortality based on number dead compared with checks on fourth day after exposure to treated foliage.

SMALL-PLOT AND GREENHOUSE TESTS.—In the small-plot tests, 10 by 10-ft. units were sprayed or dusted with each formulation. The grasshoppers for these tests were confined in screen cages on the treated plots. Some of the insects were placed on the test plots before treatment, and others were caged over the treated area 30 minutes after spraying or dusting. These grasshoppers were about 90 per cent nymphs of *Melanoplus femur-rubrum* (Deg.). Results of small-plot tests appear in table 1.

The data in table 1 make it clear that all three compounds must act both as stomach poisons and as contact insecticides in these tests. In every instance, kills were faster and more complete when both the insects and the foliage had been treated than when the grasshoppers were placed on the plots after the foliage was sprayed or dusted. This was especially true with formulations of benzene hexachloride, which showed less residual effect than either chlordane or *Toxaphene* at the concentrations tested. On the other hand, benzene hexachloride showed a much more powerful contact action than either chlordane or *Toxaphene*.

In order to check further the persistency of residual action of these materials, potted bean plants were sprayed with technical DDT, chlordane, *Toxaphene*, and a sample of 37 per cent γ-benzene hexachloride, all at 1 to 500 dissolved in a solution of 65 per cent acetone and 35 per cent distilled water, plus sodium decylbenzenesulfonate[7] at 1 to 3000 as a wetting agent. Adults of *Melanoplus differentialis* (Thos.) were caged over two pots of each treatment at intervals of 1, 3, 6, 12, 19, and 33 days after the plants were sprayed. Figure 1 is a summary of these tests.

In a similar series of tests, potted bean plants were sprayed with wettable powders of the four compounds. DDT, chlordane, and *Toxaphene* were used at 1 lb. actual toxicant per 100 gals., and a 5.75 per cent γ-benzene hexachloride wettable powder was sprayed at 3 lbs. per 100 gals. Adult differential grasshoppers were caged over the various treatments at intervals of 1, 7, 11, and 16 days after treatment. Results of these tests are graphed in figure 2.

[1] Costs of publication paid by the authors to secure early publication.

[2] This study was supported in part by a grant from the Velsicol Corporation of Chicago, Illinois.

[3] Associate Entomologist, Illinois Natural History Survey and Entomologist, Illinois Natural History Survey & Illinois Agricultural Experiment Station, respectively.

[4] Technical chlordane: "A commercially produced chemical, containing 60–75% of chlordane, together with 25–40% of related compounds occurring in the normal manufacturing processes which are toxic to insects. Chlordane: 1,2,4,5,6,7,8,8-octachloro-4,7-methano-3a,4,7,7a-tetrahydroindane." (Statement recently released by the U.S.D.A.)

[5] 2,2-bis(p-chlorophenyl)-1,1,1-trichloroethane.

[6] Chlorinated camphenes. 67 to 69% camphene.

[7] *Santomerse D.*

Table 1.—Small-plot tests of chlorinated hydrocarbons on *Melanophus femur-rubrum* nymphs in alfalfa One group of grasshoppers caged on plots before treatment (dusted or sprayed along with the alfalfa), and another group caged on plots 1/2 hour after treatment (alfalfa only sprayed or dusted).

Compound and Formulation	Rate Actual Toxicant per Acre	Grasshoppers Caged on Plots Before Spraying or Dusting		Grasshoppers Caged 30 Min. After Treatment	
		Days	% Kill	Days	% Kill
γ-Benzene hexachloride 1% dust	0.15 lbs. gamma	1 2	89.2 95.6	7	10.1
γ-Benzene hexachloride 1% dust	0.3 lbs. gamma	1 2	84.5 91.0	4 7	5.0 20.0
γ-Benzene hexachloride 0.5% dust	0.15 lbs. gamma	1 2 4 5 7	72.6 83.4 91.4 92.0 93.1	7	11.3
γ-Benzene hexachloride 0.5% dust	0.3 lbs. gamma	1 2	88.7 94.0	3	14.3
Chlordane, 2% dust	0.5 lbs.	1 2 4	32.5 62.5 66.3	2 7	8.5 36.6
Chlordane, 2% dust	1.0 lbs.	1 2	73.1 98.1	2 4 5 7	4.9 66.0 83.5 93.2
Toxaphene, 2% dust	1.0 lbs.	4	73.1	5	19.7
γ-Benzene hexachloride, 5.75% wettable powder	0.173 lbs. gamma			7	25.3
Chlordane, 50% wettable powder[1]	1.0 lbs.			7	31.1
Toxaphene, 25% wettable powder	3.0 lbs.			2 4 5 7	8.2 78.1 83.6 91.8
Benzene hexachloride (10% gamma)..20% Xylene.....70 *Atlox 1045A*.....10 by wt.	0.075 lbs. gamma	2 3 5	40.0 72.3 80.0	5	5.2
Benzene hexachloride, same formulation	0.15 lbs. gamma	2 3 5	54.9 71.4 78.0	5	13.5
Benzene hexachloride, same formulation	0.3 lbs. gamma	1	100.0	6	7.4
Benzene hexachloride (10% gamma)..20% Dioxane.....70 *Atlox 1045A*.....10 by wt.	0.3 lbs. gamma	1	100.0	6	23.3
Chlordane.....62% Xylene.....33 *Atlox 1045A*..... 5 by vol.	8 oz.	5	59.8	5	42.0
Chlordane, same formulation	1.0 lb.	1 2	62.9 95.9	6	78.8
Toxaphene, 50% emulsion concentrate by wt.	3.0 lbs.	1 2	62.0 92.0	3 4 6	22.2 31.1 61.1
Control, no treatment		7	2.2		

[1] Poor mix in sprayer. Material formed agglomerates.

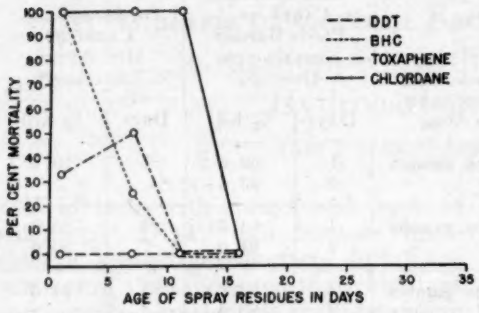

FIG. 2.—Persistency of toxicity of residues of chlorinated hydrocarbons on plants. Potted bean plants sprayed with wettable powders of the four chlorinated hydrocarbons and infested with adult *Melanoplus differentialis* at various dates after spraying. Mortality based on number dead compared with checks on fourth day after exposure to treated foliage.

The results presented in figures 1 and 2 represent the combined effects of persistency of the compounds and reduction in dosage due to plant growth. In the first series of tests, a relatively large amount of toxicant was deposited on the sprayed foliage. In the tests on wettable powders, the dosages more closely approached those applied in the field. Where the dosage was high, DDT gave fair kills through the twelfth day after spraying. The DDT residue from the application of the wettable powder, however, was below the threshold of toxicity for this compound even one day after the spray was applied. The benzene hexachloride deposits in both instances showed the shortest period of effectiveness, and the chlordane was toxic for an appreciably longer time than any of the other compounds.

In a third series of tests, ten different formulations of chlordane emulsion concentrates were prepared. These formulations included variations in solvents and in types and amounts of emulsifiers. Potted beans sprayed with the various preparations at 1 lb. actual chlordane per 100 gals. were exposed to the weather and sprinkled daily. No significant differences among the formulations could be determined when the sprayed plants were infested with *Melanoplus differentialis* adults at intervals from 1 to 18 days after spraying. There was, however, some indication that the water-soluble type of emulsifier produced less persistent residues than those resulting from the use of an oil-soluble emulsifying agent. Differences in solvents and in amounts of emulsifiers had no apparent effect on initial toxicity nor persistency of residues.

In some of the field work, crops sprayed with chlordane resisted reinfestation from adjacent, heavily infested areas so completely that a powerful repellent effect for this compound was assumed. Some of the farmers and fruit growers who used chlordane reported also a definite repellent action. An attempt was made, therefore, to get some indication of the degree of repellency to grasshoppers of plants sprayed with all four hydrocarbons.

In the first tests, 5 *Melanoplus differentialis* and 5 *M. femur-rubrum* adults were caged over pots each containing three bean plants. In each pot, one plant was left unsprayed, and the other two were sprayed with different chlorinated hydrocarbons, so that in a series of pots, each of the four materials was compared with each of the others and with a check in the same group of plants. Results of this test were inconclusive: It appeared that the grasshoppers fed on the first plant they happened to come to, without regard to the material with which it had been sprayed.

It was concluded that probably the inability of the grasshoppers to select between different treatments or between a treated and an untreated plant in this experiment was the result of their being confined in too small a space. Another method of test, therefore, was set up in which corn and beans were planted in flats 14 by 20 inches, and when the plants were about 5 to 6 inches tall, 4 flats were sprayed with each of the chlorinated hydrocarbons (using a 37 per cent γ-benzene hexachloride sample) and 4 were kept unsprayed as checks. The compounds were applied in acetone-water solution to eliminate possible complications from emulsifiers and solvents.

One flat of each treatment was placed in a large screen house in which several hundred adult differential grasshoppers were confined. Another series of flats was exposed on the University South Farm near soybeans, where the population of grasshoppers was mostly *Melanoplus differentialis*. The other two series were placed in an orchard near Urbana, in spots heavily infested with *M. femur-rubrum*. The arrangement of the flats in each group was changed daily: Sometimes they were placed in a straight line, some-

times arranged in a circle, and sometimes placed in a compact group. The position of a treatment relative to other treatments and to the check was changed daily also. During the week to 10 days that these tests were running, no significant difference could be detected between any two treatments or between any treatment and the check. In all four series it appeared that the flat sprayed with DDT showed slightly more feeding than the check and that the other 3 treatments had slightly less feeding than the check. These differences were so small, however, that no significance was ascribed to them.

The results of these repellency tests make it very difficult to interpret some of the field data. If chlordane is not repellent, why is there such a sharp line of division between sprayed and unsprayed areas for as long as a week after treatment? It has been suggested that the vapor of chlordane may be repellent. When a large area is sprayed with chlordane, there may be a blanket of vapor around the treatment which repels grasshoppers. This seems to be the only logical explanation, since these tests definitely indicate that there is no tactile nor gustatory repellency to chlordane-sprayed foliage.[1]

It has been claimed for benzene hexachloride that in addition to the initial kill of grasshoppers by contact with or feeding on this compound, or by both, there is a considerable kill also from live grasshoppers eating those which died of benzene hexachloride poisoning (Anonymous 1946). Results with benzene hexachloride as a stomach poison led to some doubt of this claim. Moreover, it is unlikely that the material remains toxic in the body of the grasshopper. Finally, our experience has been that cannibalism among grasshoppers under field conditions in Illinois is rare. Nevertheless, an attempt was made to check the accuracy of this claim and to find out also whether compounds other than benzene hexachloride might show such an effect.

Twelve 1-foot-cube screen cages with plywood bottoms were used for these tests. Ten adult differential grasshoppers were placed in each cage with 10 dead grasshoppers killed by different treatments. No food other than the dead grasshoppers was given to the test insects (except the checks), but after the first 24 hours, each cage was kept supplied with water. Grasshoppers to be killed by stomach-poison action were fed foliage heavily sprayed with the four test compounds. Those to be killed by contact were treated by putting small amounts of acetone solutions of the test compounds on the metathoracic tergum. In other cages, unpoisoned grasshoppers, some killed by heat and others by etherization, were offered as food.

In none of the cages were more than 66 per cent of the dead insects eaten after 10 days, even when no other food was available, and in most of the cages, less than 40 per cent of the insects were eaten. The rate of mortality among the test insects was about the same for those fed treated grasshoppers as for those which fed on grasshoppers which died of physical causes. It appeared also that dead grasshoppers are not suitable food, since the rate of dying among the individuals caged without food was about the same as the rate among those given unpoisoned insects for food. It was concluded from these results, therefore, that cannablism cannot be an important source of mortality in the control of differential grasshoppers.

LABORATORY TESTS.—The chlorinated hydrocarbons were first evaluated in the laboratory against grasshoppers in tests of residual surfaces. Removable glass plates which fit into a framework to form a cage were sprayed with predetermined dosages of 37 per cent γ-benzene hexachloride and technical DDT, chlordane, and *Toxaphene*. Second- to fourth-instar *Melanoplus femur-rubrum* nymphs were introduced into the cages for various lengths of time, after which they were kept for three days in screen cages, a mortality record being taken each day. From 20 to 175 insects were used in each test, the average being about 50.

Results of these tests indicated that the 37 per cent γ-benzene hexachloride had the greatest toxicity, followed closely by chlordane; *Toxaphene* appeared to be the least toxic of all. Results on *Toxaphene* and benzene hexachloride were characterized by a narrow spread between the kill at 24 hours and that at 72 hours, relative to the spread during the same interval in the results with DDT and especially

[1] This method of testing preferential feeding of grasshoppers is a modification of the one described by Bigger *et al.* in a manuscript to be published in an early issue of the Journal of the American Society of Agronomy.

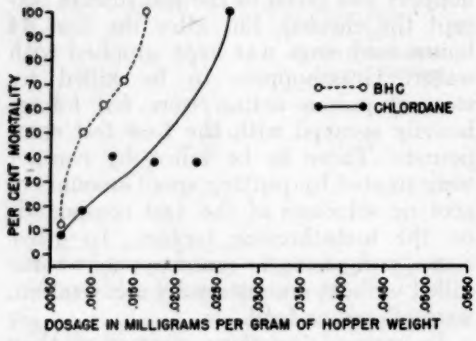

FIG. 3.—Relative toxicity of 37 per cent γ-benzene hexachloride and technical chlordane as contact insecticides to adults of *Melanoplus differentialis*. Toxicants applied in acetone solutions to metathoracic and first abdominal terga.

with chlordane. Throughout this work, benzene hexachloride seemed to have a sharply defined threshold of toxicity above which it is extremely active, and below which, it is almost completely inactive. Possibly *Toxaphene* works in the same way as a contact insecticide.

Laboratory studies were directed primarily toward the determination of the relative toxicity of the 4 chlorinated hydrocarbons as contact insecticides and as stomach poisons. For this work only adult, differential grasshoppers were used. These were collected at intervals and placed in a screen house with an abundance of food until needed. Each insect that died during a test was examined for parasites or evidence of disease. If either was found, the test was discarded. The data presented here, therefore, include no results on grasshoppers known to have been parasitized or diseased.

Just before being used in a test, each insect was weighed to the nearest tenth of a milligram. In the contact tests, the compounds, dissolved in acetone, were applied to the metathoracic and first abdominal terga by means of a small, wire loop. With the insecticide on this area of the body, the grasshoppers could not brush it off or otherwise disturb it with any of their appendages. As soon as the acetone had evaporated, the insects were placed in individual screen cages supplied with fresh food. Tests were checked and the grasshoppers given new food daily for 7 to 10 days. The quantity of compound transferred to the bodies of the insects was determined by careful weighing of long series of similar deposits on glass cover slips. Variations in dosage were effected both by varying the concentration of test solutions and by varying the number of loops of solution transferred to the bodies of the grasshoppers. Dosage was computed as the ratio of compound (in milligrams) to the weight of the insect in grams (*i.e.*, "milligrams of toxicant per gram of grasshopper weight").[1]

In the stomach-poison tests, the grasshoppers were weighed and placed in screen cages without food. Then one square inch of fresh corn leaf, sprayed (by means of a modified Tattersfield apparatus) with a known amount of the test compound, was introduced into the cage. This was the only food available to the insect for the first 18 to 24 hours of the test. After that time, the test leaf section was removed and the amount of feeding on it measured. From this measurement, it was possible to determine rather exactly the actual weight of compound consumed by the insect. On the second day of test and each day thereafter, the grasshoppers were given fresh, unsprayed foliage. The dosage figures are the mg. of toxicant consumed per gram of insect weight.

For both contact and stomach-poison tests, the 37 per cent γ-benzene hexachloride and technical grades of chlordane *Toxaphene*, and DDT were used.

Figures 3 and 4 are summaries of the results of the contact tests, expressed both as mortality 4 days after treatment and as survival time of those grasshoppers which

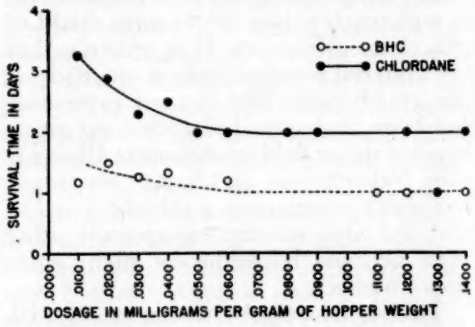

FIG. 4.—Relative rapidity of action of 37 per cent γ-benzene hexachloride and technical chlordane applied in acetone solutions to metathoracic and first abdominal terga of adult *Melanoplus differentialis*. Curves are averages of survival times of those individuals which died at the various dosage levels.

[1] This technique was adapted from one developed by Dr. J. F. Yeager (private communication).

died after treatment. Mortality data for the stomach-poison tests are graphed in figure 5.

Neither *Toxaphene* nor DDT appears in figures 3 and 4, because the highest dosages of these compounds tested (0.7496 mg./gram for *Toxaphene* and 1.6347 mg./gram for DDT) were still below their median lethal dosages. These figures show that 37 per cent γ-benzene hexachloride as a contact poison is effective at lower concentrations and acts more quickly than chlordane. The curves in figure 3 are not necessarily true dosage-mortality curves, for although the tests included 74 individuals treated with benzene hexachloride and 77 treated with chlordane, there were too few replicates at the various dosage levels for accurate evaluations. Nevertheless, examination of the individual test results strongly suggests that the LD-50 for 37 per cent γ-benzene hexachloride lies between 0.0110 and 0.0130 mg./gram. Above 0.0129, only 3 of 41 grasshoppers lived longer than 2 days, and below 0.0112, only 5 of 22 insects died earlier than the seventh day.

Similarly, the LD-50 for chlordane as a contact poison must lie between 0.0195 and 0.0220 mg./gram. Above 0.0218, only 3 of 32 individuals survived longer than 4 days (only 5 longer than 3 days), and below 0.0195, only 11 of 40 died before the fourth day.

The results of stomach-poison tests indicated that, again, our highest dosages for DDT (0.2592 mg./gram) were below the LD-50 for this compound. The results of tests on *Toxaphene*, however, showed a sharp break between 0.0860 and 0.1050 mg./gram, which dosages are taken to be the limits of the LD-50 range for this compound.

Results with both benzene hexachloride and chlordane as stomach poisons were rather variable. Again, the curves in figure 5 are meant merely to show relationships in toxicity and may not be accurate dosage-mortality curves. Too few tests were run on chlordane and benzene hexachloride at the lower dosage levels to enable us to be sure of the shape of these curves. Our results on 65 individual tests with each compound, however, indicate an LD-50 for chlordane as a stomach poison to be in the vicinity of 0.0140 mg./gram. Benzene hexachloride more effective than chlordane as a contact insecticide, has an LD-50 of about 0.0350 mg./gram as a stomach poison. These results agree fairly well with those reported by Kearns, *et al.* (1945) who found the median lethal dosage for chlordane as a stomach poison to lie between 0.0125 and 0.0250 mg./gram. For pure γ-benzene hexachloride, these authors placed the stomach-poison LD-50 at 0.0050 to 0.0100 mg./gram. According to these figures, the LD-50 for 37 per cent γ-benzene hexachloride would be 0.0140 to 0.0280

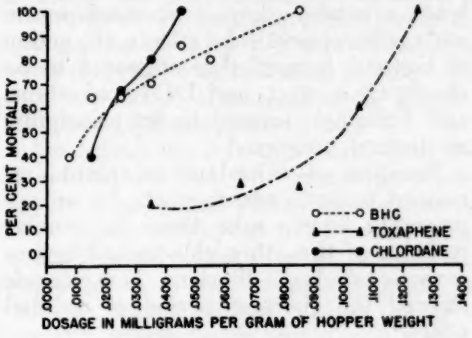

FIG. 5.—Relative toxicity of 37 per cent γ-benzene hexachloride, technical chlordane, and *Toxaphene* as stomach poisons to adult *Melanoplus differentialis*. Grasshoppers fed on square-inch leaf sections sprayed with known amounts of the compounds.

mg./gram. The discrepancy of these results on benzene hexachloride may be due in part, at least, to the differences in techniques employed. Since, in our tests, the grasshoppers were given 18 to 24 hrs. in which to feed on the treated foliage, it is possible that some of the insects did not feed at all until well toward the end of that period, by which time much of the material may have been lost through volatilization.

The rates of action of chlordane, benzene hexachloride, and *Toxaphene* as stomach poisons at dosages above their LD-50's are remarkably uniform. In these present tests, grasshoppers fed lethal dosages of benzene hexachloride and chlordane died, in almost every instance, between 1 and 2 days after the tests were begun. Those killed by feeding on *Toxaphene* were dead at the end of the second day. This relationship was valid even at dosages well above the LD-50 range. At dosages within and below the LD-50, benzene hexachloride still killed in less than two days or not at all. With *Toxaphene*, there was a gradual increase from

days to 3.5 days in the survival time of the grasshoppers which died, as dosages decreased from LD-50 to LD-0. Too few tests were run below the LD-50 for chlordane to show the relationship between dosage and survival time, but results of other experiments indicate that, like *Toxaphene*, a decrease in dosage from LD-50 to LD-0 would effect an increase in survival time.

CONCLUSIONS.—Although the control of grasshoppers by the use of sprays and dusts of chlorinated hydrocarbons represents a combination of stomach-poison and contact-insecticidal effects, the action of benzene hexachloride appeared to be chiefly by contact, and DDT, chlordane, and *Toxaphene* seemed to act principally as stomach poisons.

Residues of chlordane on plants remained toxic to grasshoppers for an appreciably longer time than did similar residues of the other chlorinated hydrocarbons studied. Benzene hexachloride showed the shortest period of residual effect.

The persistency of chlordane residues on plants exposed to sunlight, wind, and rain was independent of the amount of emulsifier or type of solvent used in the emulsions. Residues from emulsions made with water-soluble emulsifiers were somewhat less resistant to weathering than those made with oil-soluble agents.

No tactile or gustatory repellency to grasshoppers could be demonstrated for any of the four compounds tested.

Cannibalism among *Melanoplus differentialis* adults cannot be an important source of mortality in the control of these insects.

Fresh deposits of 37 per cent γ-benzene hexachloride on glass plates were more toxic to *Melanoplus femur-rubrum* nymphs than were similar deposits of the other chlorinated hydrocarbons. Chlordane deposits were only slightly less toxic, and *Toxaphene* deposits were the least toxic of the four.

The 37 per cent γ-benzene hexachloride was approximately 1.75 times as toxic to adult *Melanoplus differentialis* as was chlordane as a contact insecticide. Although the median lethal dosages for *Toxaphene* and DDT by contact action were not determined, the tests indicated that the 37 per cent γ-benzene hexachloride is more than 62 times as toxic as *Toxaphene* and more than 136 times as toxic as DDT in contact effect.

Those grasshoppers killed by the contact effect of 37 per cent γ-benzene hexachloride died usually during the first 24 hours; very few survived more than 2 days, regardless of the dosage of benzene hexachloride used. The contact action of chlordane was slower at all dosages and showed a progressive decrease in survival time with an increase of dosage below and within the LD-50 range. Even above these dosages, chlordane rarely produced death in less than 2 days.

As a stomach poison, chlordane was approximately 2.5 times as effective as 37 per cent γ-benzene hexachloride and was nearly 7 times more active than *Toxaphene*. Chlordane was more than 18 times as toxic as DDT in stomach-poison effect.

The speeds of action of chlordane, 37 per cent γ-benzene hexachloride, and *Toxaphene* as stomach poisons at dosages above their LD-50's were almost uniform. —3-3-47.

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Dr. Richard H. Daggy, formerly assistant professor of entomology at the University of Minnesota, has accepted a position as entomologist for the Arabian American Oil Company. He will leave for Saudi Arabia shortly where he will work in malaria control and allied medico-entomological problems. His new address will be in care of the Arabian American Oil Company, Dhahran, Saudi Arabia.

Insecticidal Sprays and Dusts for Control of Grasshoppers[1,2]

CARL J. WEINMAN, G. C. DECKER, and J. H. BIGGER[3]

Many Illinois farmers, particularly fruit growers and truck gardeners, for years have insisted that the use of poison baits represents an ineffective and inefficient method of approaching the problem of grasshopper control. Therefore, when preliminary tests showed that chlordane was extremely toxic to grasshoppers, thereby confirming the findings of Kearns *et al.* (1945). the writers embarked on an extensive series of laboratory and field tests in an attempt to develop a practical spray or dust that might effectively and economically control grasshoppers and at the same time prove acceptable to those growers who object strenuously to the use of poison baits.

Field experiments involving approximately 2000 acres of mixed crops were set up in 6 counties, and individual growers conducted their semi-commercial tests in at least 10 additional counties. The grasshopper population was almost entirely *Melanoplus femur-rubrum* (Deg.) and *M. differentialis* (Thos.) with the relative abundance of the two varying in the different areas. Three chlorinated hydrocarbons[4] were used as sprays or dusts in the field experiments.

SPRAYS AND DUSTS APPLIED WITH GROUND EQUIPMENT.—The first field tests were designed primarily to determine the relative merits of two chlordane concentrate emulsions containing different amounts of the emulsifier, *Atlox 1045A*.

Formulation T-100		*Formulation T-101*	
Chlordane	62 per cent	Chlordane	50 per cent
No. 9 oil	33	No. 9 oil	30
Atlox 1045A	5	*Atlox 1045A*	20

Two red clover fields in Bond County were selected for the tests. Half-acre plots were treated in Field A where the infestation ran 25 to 30 grasshoppers per square yard (mostly second and third-instar *M. differentialis*), and one-acre plots were treated in Field B where the infestation ran 35 to 40 grasshoppers per yard. A 100-gallon power sprayer was used to apply 8 to 20 ounces of emulsion concentrate in 100 gallons of spray per acre. The plots were sprayed on June 28 and revisited on July 2 (96 hours after treatment). The results obtained are given in table 1.

By July 2, the infestation had been reduced to less than one grasshopper per square yard in both plots, but the insects were still abundant (25 to 35 per sq. yd.) in the field up to the edge of the plots. It appeared as if the chlordane formed a definite barrier across which the unsprayed grasshoppers would not move. On July 9, some grasshoppers had begun to migrate into the treated areas, but control by the treatments was still evident at that time.

Inasmuch as the *T-101* gave as good control as the *T-100* treatments, it appeared that with an orchard sprayer, at least, the degree of emulsification and wetting has little or no effect on the toxicity of chlordane to grasshoppers. Moreover, the results obtained by growers who used 3-gallon hand sprayers and other simple equipment indicated that the method of application also may be unimportant in control.

An infestation of *Melanoplus femur-*

Table 1.—Grasshoppers per sq. yd. in 0.5 acre (A) and 1 acre (B) plots 96 hrs. after spraying with chlordane emulsions.

MATERIAL	AMT. PER 100 GALS.	TOXICANT PER ACRE	GRASSHOPPERS PER SQ. YD.	
			A	*B*
Chlordane 50%[1]	1.25 pts.	1.0 lb.	<1	<1
Chlordane 62%[2]	0.5 pts.	0.5 lb.	<1	—
Chlordane 62%[2]	1.0 pts.	1.0 lb.	<1	<1
Check			25	35

[1] Formulation *T* 101.
[2] Formulation *T* 100.

[1] Costs of Publication paid by the authors to secure early publication.

[2] This study was supported in part by a grant from the Velsicol Corporation of Chicago, Illinois.

[3] Associate Entomologist, Illinois Natural History Survey; Entomologist, Illinois Natural History Survey and Illinois Agricultural Experiment Station; and Associate Entomologist, Illinois Natural History Survey, respectively.

[4] Designation of compounds used in these tests:
DDT: 2,2-bis(p-chlorophenyl)-1,1,1-trichlorocethane.
Benzene hexachloride. 1, 2, 3, 4, 5, 6 hexachlorocyclohexane.
Technical Chlordane: "A commercially produced chemical, containing 60–75% of Chlordane, together with 25–40% of related compounds occurring in the normal manufacturing processes which are toxic to insects. Chlordane: 1,2,4,5,6,7,8,8-octachloro-4,7-methano-3a,4,7,7a-tetrahydroindane." (Statement recently released by the U.S.D.A.)

rubrum averaging 25 to 30 grasshoppers per square yard (50 per cent adults) in a non-bearing orchard near Urbana afforded an opportunity for further field tests. On August 20, five 0.5 acre plots were dusted early in the morning while the grass and weeds were wet with dew, and after the dew was gone a duplicate set of plots was dusted. The materials used, rates of application, and the results obtained are shown in table 3.

There was no apparent difference between the dusts applied on wet and dry foliage, and all are considered together as replicated plots. By 1:30 p.m. on August 20 (5 to 6 hrs. after treatment) practically all of the grasshoppers in the 0.5 per cent and 1 per cent benzene hexachloride plots were down, but little or no paralysis was noted in the other plots. These observations serve to emphasize the quick action that may be expected from the use of benzene hexachloride and are in agreement with the findings of Brett & Rhoades (1946). They reported that benzene hexachloride was very effective 24 to 30 hours after dusting, but that chlordane, even at 10 pounds of a 10 per cent dust per acre, was "not satisfactory." Speed, however, may not be as important as the final result. As shown in table 2, benzene hexachloride had reached its maximum effectiveness in 24 hours and reinvasion began on the second day after dusting, whereas the insects continued to die in the chlordane plots for at least 4 days after treatment.

In further tests in the same orchard, dusts were compared with sprays of emulsion concentrates and wettable powders. The formulations used are shown in table 2.

All applications were made on September 4, the emulsions at 10 to 12 a.m., the wettable powders at 2 to 4 p.m., and the dusts at 7 to 8 p.m., at which time conditions for dusting were perfect. By the morning of September 5, it appeared that the wettable powders were giving quicker results than the emulsions. By afternoon of that day, however, the following relationships were observed:

Benzene hexachloride (full strength): Dusts > emulsion > wettable powder.
Benzene hexachloride (half strength): Dusts = emulsion > wettable powder.
Chlordane (full strength): Emulsion = wettable powder > dust.
Chlordane (half strength): Emulsion > wettable powder > dust.
DDT: No appreciable effect.

Throughout the tests, the materials maintained the following relationship in effectiveness: Benzene hexachloride (full strength) = chlordane (full strength) > chlordane (half strength) > benzene hexachloride (half strength) > DDT, except that the chlordane dusts were less effective than the benzene hexachloride dusts. The results indicate that if dusts are to be used, benzene hexachloride may be preferred to chlordane, but that chlordane sprays are as good as benzene hexachloride dusts at the concentrations tested and have a longer residual effect. DDT was not effective in any of the formulations tested.

Table 3.—Number of live grasshoppers per sq. yd. observed 24, 48, and 96 hrs. after 0.5 acre weedy grass plots were dusted with various insecticides (population 25 per sq. yd. when treated).

Material	Pounds per Acre		No. Live Grasshoppers per Sq. Yd.		
	Dust	Toxicant	24 hrs.	48 hrs.	96 hrs.
Benzene hexachloride 1% Gamma	30	0.3	0	2	8
Benzene hexachloride .5% Gamma	30	0.15	3	5	10
Chlordane 1%	20	0.2	15	8	5
Chlordane .5%	20	0.1	20	15	10
DDT 5%	40	2.0	23	23	22
Check	—	—	25	25	22

Table 2.—Formulations used in Urbana orchard plots.

Dusts		Emulsion Concentrates		Wettable Powders		Toxicant
Lbs./acre		*Pts./acre*		*Lbs./acre*		*Lbs./acre*
Chlordane,	5%—20	Chlordane[1]	— 1.0	Chlordane (50%)	—2	1.0
Chlordane,	2%—25	Chlordane	— 0.5	Chlordane (50%)	—1	0.5
γ-Benzene hexachloride,	1%—30	Benzene hexachloride[2]	—24.0	Benzene hexachloride (5.75%)[4]	—3	0.3[4]
γ-Benzene hexachloride,	½%—30	Benzene hexachloride	—12.0	Benzene hexachloride (5.75%)	—1.5	0.15
DDT,	5%—20	DDT[3]	— 4.0	DDT (50%)	—2	1.0

[1] Chlordane—62%, Xylene—33%, *Atlox 1045A*—5% (by vol.).
[2] Benzene hexachloride (10% gamma crude) dissolved in dioxane and AR-50 (methylated naphthalenes) and emulsified with *Atlox 1045A*.
[3] DDT, 25% (by wt.) in AR-60 (methylated naphthalenes), emulsified.
[4] The benzene hexachloride wettable powder contained only 5.75% gamma isomer, instead of 10% as intended, and these powders therefore had only about half as much gamma isomer (0.1725 and 0.0863 lb./acre) as the corresponding dust and emulsion plots.

To determine the hazard to poultry feeding on poisoned grasshoppers, a cage containing 5 large, white-leghorn hens was placed on each plot. On September 5, each cage received 200 cc. of dead grasshoppers collected from within the plot. For the next 4 days, each cage was given 400 cc. of grasshoppers per day. One week later, only one chicken had died, and that one was in the control group which had been fed no treated grasshoppers. No off flavor could be detected in any of the birds when prepared and served to 60 people.

AERIAL APPLICATION OF SPRAYS.—The farmers in Bond County who observed the first tests were enthusiastic, but they had no power spraying equipment; and besides, they were unwilling to have trucks or tractors drive through their clover fields, many of which showed promise of setting a fair crop of seed. They practically insisted on establishing large-scale tests with airplane sprays.

About 100 acres were sprayed on July 18, and an additional 250 acres were sprayed by 5:00 p.m. the following day. Hard rains started at 9:00 p.m. that night and continued all the next day. The 350 acres sprayed July 18 and 19 included red clover, oats and wheat stubble seeded to clover, grass pasture, corn, soybeans, alfalfa, and fencerows. The formulations tested are given in table 4.

In general, the results of these tests were surprisingly good. Formulation C was definitely slow in its action, and overall results with C were not quite as good as with A and B. The C formula also caused a burn wherever the droplets fell on soybeans, corn, buttonweed, and to a less extent, on clover. This is not surprising, however, for the temperature was 106° F. with bright sunshine at the time these sprays were applied. Under such conditions, we anticipated some injury from the other formulations also, but in no instance was any injury observed from the use of formulae A and B.

With a few exceptions, all of the pound-per-acre tests gave complete or almost complete kills of grasshoppers, and there was no apparent difference between the use of 1 pound in 2 gallons or in 5 gallons of spray per acre. Comments, therefore, are confined to the exceptions and the dosages other than 1 pound per acre.

A 20-acre field of stubble clover was sprayed with chlordane at 0.4 lb. per acre in 2 gallons of water, and 20 acres of rank seed clover just across the road was sprayed with the same solution at 5 gallons per acre (1 lb. chlordane). Both fields showed almost complete cleanup of grasshoppers. At the same time, in two small clover fields (total, 12 acres) sprayed with the same formulation at approximately 5 gallons per acre, control was very poor. Perhaps the small fields were hard to hit and much of the spray drifted away. Likewise, where only fencerows were sprayed, results were generally poor, seldom showing more than 50 per cent control.

Probably the best test of formulation C was in a 20-acre clover field, half of which was sprayed with C and the other half, with B, both at 1 pound chlordane per acre. One day after spraying, there was an estimated 50 per cent dead in plot B and only 25 per cent in plot C. Observations made 5 days later showed 95–98 per cent kill in B and 50–60 per cent in C. When examined again about 2 weeks later, however, there were hardly

Table 4.—Formulations and rates of application used in airplane spraying experiment, Bond Co., July 18-19.

FORMULATION	DILUTION AND APPLICATION RATE	TOXICANT PER ACRE	CONTROL
A. Chlordane —50% No. 9 oil —30 *Atlox 1045A*—20	1.25 pts. in 2 gal. water 0.5 pts. in 2 gal. water 1.25 pts. in 5 gal. water	1.0 lb. 0.4 lb. 1.0 lb.	Good Variable Good
B. Chlordane —50% Xylene —30 *Atlox 1045A*—20	1.25 pts. in 2 gal. water 1.25 pts. in 5 gal. water 0.6 pts. in 5 gal. water	1.0 lb. 1.0 lb. 0.5 lb.	Good Good Variable
C. Chlordane — 4% No. 9 oil —96	2 gal. per acre	1.0 lb.	Fair

any grasshoppers in either part of the field.

In a 30-acre "pasture" (heavy growth of grass and tall weeds) sprayed with B at 1 pound in 2 gallons of water, grasshopper control was adequate, but there was no apparent effect on crickets which were very abundant in the field.

In one corner of an alfalfa field sprayed at the 1-pound dosage, there was a patch of potatoes heavily infested with the two common species of blister beetles, *Epicuta solani* Werner and *E. vittata* (F). Although grasshopper control was good in the alfalfa (which included both first-year and second-year stands), there was no apparent effect on the beetles.

On July 31 and August 1, about 425 acres of crops were sprayed in Madison County. Two formulations of chlordane were used: formulation "A" described above, and a 25 per cent (by wt.) oil-free emulsion (or colloidal suspension); both materials applied at the rate of 0.8 lb. chlordane in 2 gallons water per acre. However, the substitution of a long, perforated rod for the spinner discs on the spray plane necessitated a restandardization of feed rate. Moreover, whereas whole fields were sprayed in Bond County, the Madison County farmers' spray plan looked like a patchwork quilt: One man would want 5 acres of this field and 30 feet of another sprayed; another farmer would want just certain fencerows sprayed; and still others wanted their fields sprayed for 50 to 75 feet around the edges. All of these complications made the calculation of dosage almost impossible and presented problems and hazards to the pilot which proved to be insurmountable. In consequence, a few fields were given far too heavy a dosage, and many more were sprayed with only a fraction of the calculated dosage. Results, of course, were extremely variable. Wherever the dosage of 0.8 lb. per acre actually was applied to the fields, results were good except in mature corn and clover seed fields. Even in dense stands of Sudan grass, some 4 to 6 ft. tall and so thick that one could hardly walk through them, control was adequate to excellent. Sorghum was another crop not previously sprayed, in which control was good. Control in these tests was obtained notwithstanding torrential rains which fell for 2 days, beginning in the early morning of August 2.

More aerial spraying was done in Madison and Bond Counties during the week of August 4, with better results except in corn and clover seed fields. On August 5, a beating rainstorm broke while the pilot was spraying 20 acres of spring-seeded clover and an adjoining 5 acres of soybeans. When these fields were checked 2 days later, many dead and dying grasshoppers were observed in the soybeans, but control was not good. In the clover, however, hardly any dead grasshoppers could be found. There was no apparent change several days later. In this test, where the rain fell before the spray had a chance to dry on the plants, most of the deposit was presumably washed off.

During the week of August 12, 300 acres of corn, soybeans, lespedeza, clover, and stubble were sprayed in Montgomery County. In this area only the 25 per cent oil-free emulsion was used at the rate of 1 lb. chlordane in 2 gallons of water per acre. The fields were checked 5 days after the spray was applied, and although steady rains started on the third day after treatment and continued for several days, control was excellent except in old clover seed fields.

AERIAL APPLICATION OF DUSTS.—On the evening of August 1, strip tests as shown in table 5 were run in corn and seed clover on a farm in Bond County. Showers fell on these plots from 3:00 a.m. until noon on August 2, and 2.35 inches of rain fell here during August 2 and 3. After the first showers, dust could barely be discerned on some corn leaves, and by August 3 no sign of any dust could be seen. Quite obviously the dusts did not withstand the rain as well as did spray deposits; but if allowance is made for

Table 5.—Formulations and rates of application used in airplane dusting experiments, Bond Co., Aug. 1.

Formulation	Pounds per Acre		Efficiency Ratings[1]		
	Dust	Toxicant	24 hrs.	48 hrs.	72 hrs.
1. Benzene hexachloride 1% Gamma	30	0.3	1	3	3
2. Chlordane 2%	20	0.4	3	3	4
3. Chlordane 5%	30	1.5	2	1	1
4. Benzene hexachloride 0.5% Gamma	30	0.15	4	4	5
5. Chlordane 5%	10	0.5	3	2	2
6. Check	—	—	—	—	—

[1] Population 25/sq. yd. at start, 90% adult *Melanopeus differentialis*.

Best treatment (rated 1) reduced population to 4 per sq. yd., poorest (rated 5) about equal to check.

weathering, the results obtained are in fair agreement with those obtained in the more critical tests run with ground equipment at Urbana. Early in this experiment, the 1 per cent benzene hexachloride dust looked much better than any of the chlordane plots. Later, however, the chlordane showed a greater effect (especially in the corn) than the benzene hexachloride. The latter gave better results in clover than in corn, but chlordane was better in corn than in clover. This again points to a stomach-poison effect for chlordane and probably to a contact effect for benzene hexachloride.

During the third week in August, an airplane dusted 50 acres of soybeans on a farm in Adams County using a 1 per cent benzene hexachloride dust at 25 lbs. per acre. The owner of the farm reported that the kill varied from 50 per cent at the leeward side of the field to 90 per cent at the windward side—although both the farmer and the pilot maintained that conditions for dusting were nearly perfect, with very little wind. The observation that there was almost no kill until the third day after dusting is difficult to rationalize with the results of other tests, all of which indicated benzene hexachloride to be a very quick-acting poison.

GROWER EXPERIENCES.—At least 50 growers obtained materials and conducted experiments of their own. Their experiences and results as reported to us are definitely in line with the results obtained in our experiments and are not repeated here except as they have a bearing on the general discussion and conclusions. The observations of two growers are of special interest.

Mr. Clayton Brown, of Vermont (Fulton County), has 10 acres of apple trees, in part interplanted with peaches, set in the middle of his farm. For several years past grasshoppers have caused considerable damage to his fruit and trees. In 1946, the orchard was bordered on three sides by grass pasture and on the fourth side, by oats. In mid-July there were 10 to 15 grasshoppers per square yard overall, with spots of infestation as high as 35. The fence rows and adjacent field margins had 35 or more grasshoppers per square yard, and the fields themselves were somewhat more heavily infested than the orchard.

Mr. Brown first sprayed the entire orchard on July 18 and 19, using *T-101* at 20 ounces per acre (1 lb. chlordane) in 50 gallons of water. This spray gave complete control of grasshoppers in the orchard. Then he sprayed a narrow strip around the orchard on July 22 as a barrier. Eight days later he reported that there had been almost no movement of small grasshoppers into the treated area, and the few adults of *Dissosteira carolina* (L.) and *Melanoplus mexicanus mexicanus* (Sauss.) which flew in were always found in some stage of paralysis. He felt that the material must be repellent, since no grasshoppers could be found at the edge of the treated strip but they were very numerous a few steps from the margin. Mr. Brown continued to spray a strip (one swath with his 150-gallon, orchard sprayer) around his orchard at 10-day intervals for the rest of the summer. In his opinion, the spray began to lose its effectiveness somewhat after 10 days. He was, in this way, completely successful in preventing grasshopper damage to his orchard or fruit, and he concluded that "this material is effective beyond anything I had ever hoped for in controlling grasshoppers."

Messrs. Ed and Robert Kallal of Chesterfield (Macoupin Co.) used a homemade "jeep generator" (Rice *et al.* 1946) to apply *T-101* and an oil solution of chlordane. With their machine, they could apply these materials either as aerosols or as finely divided mists, and both types of dispersions were used in their tests. Results with mists were much better than with aerosols. Working with populations composed mostly of second to fourth-instar *Melanoplus differentialis*, they were able to get very good control, using mists containing chlordane at 0.4 lb. per acre. They found that the oil solution was much less effective than the water emulsions, both as aerosols and as mists.

DISCUSSION.—Grasshoppers sprayed with chlordane frequently became paralyzed within a few hours but the kill was often not pronounced until the second day. Usually the insects continued to die for 5 days to a week after application. In some fields paralyzed grasshoppers were observed as late as 2 weeks after treatment. Populations in young corn were practically wiped out in 24 hours, and nearly all the grasshoppers in soybean fields were dead in 2 days. Cleanup was slower in clover, pastures, alfalfa, and

stubble. In one clover field, for example, there was only about 25 per cent kill in a day and a half, and after 2 days it appeared that the treatment was a failure. At the end of 4 days, however, the infestation had been reduced to less than 1 per square yard, and in 6 days hardly a grasshopper could be found. Twenty rows of corn bordering this field were sprayed with the same material at the same time. Six hours after spraying, the corn ground was littered with dying grasshoppers, and the kill was estimated at 90 pe cent in 24 hours.

In the tests made in early July, the quickest kills were obtained in corn, but less than 2 weeks later results in corn were relatively poor. This difference may be correlated with the feeding habits of grasshoppers. When corn is small, the insects feed mostly on the top and outside leaves of the plants, which are exposed to the greatest concentration of spray. Later as the corn becomes more mature they feed primarily on the silks and forming ears, which are partly protected from the spray. Similarly, in soybeans the uppermost leaves, which receive the most spray, are the ones most severely attacked by grasshoppers. Good results were obtained in soybeans from early in July to the end of the season.

Tests on red clover early in July gave good results, but tests on clover seed fields made late in July or in August resulted in partial or complete failures. Here again, the difference must be the result of differences in the plants early and late in the season. While the clover is young and green, there is an abundance of foliage and blossoms to catch the spray. Later, when only bare stems are exposed, little spray contacts the plants, and the plants are by this time much less attractive to grasshoppers.

This discussion implies that although chlordane may act as a contact insecticide on grasshoppers, its primary action under field conditions is as a stomach poison. Otherwise in the August 5 test, when rain fell within 20 minutes after spraying was begun, there should have been a good kill anyway, if the effect of the chlordane was by contact. There was almost no cover in the clover field to keep the drops of spray from contacting the grasshoppers. Yet, there was no kill in the clover, although there was a fair kill in the soybeans sprayed at the same time under the same conditions.

Generally speaking, young nymphs were more easily killed than last-instar nymphs and the adults of *Melanoplus differentialis* in particular were comparatively resistant. Parts of two clover fields with grasshoppers in different stages of development were sprayed with 0.3 and 0.6 pound of chlordane respectively. Perfect control was obtained with both sprays in field A where the insects were 95 per cent half-grown, *M. differentialis* nymphs. In the second field where development was advanced, both treatments killed practically all of the nymphs and many adults, but there were still 5 to 10 hoppers per sq. yd. (80 per cent adults) in this field 6 days after treatment.

SUMMARY AND CONCLUSIONS.—1. Benzene hexachloride (gamma isomer) and chlordane are highly effective when applied as sprays or dusts for grasshopper control.

2. Benzene hexachloride in sprays or dusts at dosages in the neighborhood of 0.3 pound (gamma isomer) per acre will kill practically all *Melanoplus differentialis* and *M. femur-rubrum* present at the time of treatment.

3. Benzene hexachloride acts very rapidly but has little or no residual effect. Peak efficiency is observed in 24 hours, and thereafter reinvasion may take place.

4. Against young nymphs of *Melanoplus differentialis* and nymphs or adults of *M. femur-rubrum*, chlordane gives adequate control at a dosage of 8 ounces per acre or less. For large nymphs and adults of *M. differentialis*, dosages near 1 lb. per acre are necessary for adequate control. Dusts are less effective than sprays and may require slightly increased dosages.

5. The type of equipment and the amount of water used in dispersing chlordane has little or no effect on control, so long as the spray is applied uniformly and the dosage is adequate

6. Chlordane sprays act most quickly and most completely when applied to soybeans and young corn and are less effective in dense vegetation and on corn in silk or later stages. They are almost completely ineffective at recommended dosages on old clover (hard and dry, without green foliage or blooms) and other crops or crop residues which are almost devoid of succulent growth.

7. Oil solutions of chlordane are slower in their action than water emulsions, and they are apt to burn foliage.

8. Rain does not destroy the effectiveness of chlordane spray residues after the spray has dried thoroughly.

9. At a dosage of 1 lb. per acre, particularly if applied as a spray, chlordane is residually effective for a period of 10 days to 2 weeks.

10. Dusts and sprays (except oil solutions) of chlordane and benzene hexachloride are not toxic to most plants at the concentrations used in these experiments.

11. Emulsions of both chlordane and benzene hexachloride appear to be more effective than wettable powders.

12. Spray deposits are apparently more resistant to weathering (particularly rains) than are dusts.

13. The treatment of ditch banks, dense fencerows, and the like by airplane application is ineffective at the usual dosages of chlordane.

14. DDT was not effective in any of the formulations or dosages tested.

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Toxicity of Certain Esters of Phosphorus Acids to Aphids[1]

GEORGE F. LUDVIK[2] and GEORGE C. DECKER[3,4,5]

In recent years the unusual incidence of aphids and red spiders following the use of DDT has led to a real need for a material which would control these anthropods. The domestic shortage of nicotine, too, has aggravated the problem of aphid control. With the disclosure of the German insecticide *Bladan*, a hexaethyl tetraphosphate formulation, investigators were quick to seize upon the toxic principle as a possible substitute for noictine. Preliminary tests in this country substantiated the German claims for the effectiveness of hexaethyl tetraphosphate against aphids and also demonstrated that it is toxic to the two-spotted spider mite, *Tetranychus bimaculatus* Harvey.

To date only a limited amount of experimental data has been published on the use and scope of toxicity of hexaethyl tetraphosphate. Bronson & Hall (1946) in comparing formulations of hexaethyl tetraphosphate in dusts and in aqueous solutions found the material to be more effective than nicotine sulfate and nicotine alkaloid against the cabbage aphid and the pea aphid. Bishopp (1946) mentions that hexaethyl tetraphosphate has proved effective against the cabbage aphid and the pea aphid in laboratory tests. He also states that laboratory tests have shown it to be toxic to thrips, *Drosophila*, the citrus red spider and the pear psyllid.

Hexaethyl tetraphosphate was unique in the field of economic poisons in being an organic derivative of a phosphorus acid. Since the compound was the only one of its type known to possess toxicity to insects, the possibility that other esters of phosphorus acids might likewise be toxic could not be overlooked. Therefore, a study of various phosphorus acid nuclei with differing substituent groups was undertaken in an effort to circumscribe the toxicity of organic phosphorus compounds in general.

German sources stated that hexaethyl tetraphosphate was toxic to warm-blooded animals, but that the compound hydrolyzed very rapidly in water with a subsequent rapid loss of toxicity, thus eliminating the problem of toxic residues on food products. The results of preliminary lab-

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[4] This investigation was sponsored by the Monsanto Chemical Company of St. Louis, Missouri, who prepared and supplied all of the compounds for these tests.

[5] Costs of publication paid to secure early publication.

oratory studies, quite aside from the subject of the present paper, are in agreement with these views.

EXPERIMENTAL TECHNIQUE AND PROCEDURE.—The test insects were raised on plants grown in the greenhouse. Eggplants were infested with the green peach aphid, *Myzus persicae* Sulzer, and individual leaves were cut from the plants when they became infested with 100 to 200 aphids of various stages. The stem of the sprayed leaf was then inserted into a small paper collar, wrapped in cotton, and set into a small bottle of water. The bottle was then placed within a barrier to keep unaffected aphids from wandering.

Myzus porosus Sanderson was raised on rose plants, and this species was handled as described above, except that it was impossible to obtain as high an infestation per leaf on rose as on eggplant, and two leaves were often required to make up one test. Also, the stems of the rose leaves were placed in Z-shaped capillary tubes, one end of which passed through a two-holed rubber stopper and extended down into a vial of water. The second hole in the stopper was plugged lightly with cotton to prevent wandering aphids from falling into the water and drowning. The plug was loose enough, however, for the pressure inside the tube to remain in equilibrium with the atmospheric pressure and to allow the leaf to draw sufficient water from the vial to remain turgid for the duration of the test. The tube was filled by drawing on the open end with a pipette or by blowing on the plugged hole.

Solutions were prepared by dissolving the desired amount of compound in a stock solution of wetting agent. The stock solution was made up by dissolving one gram of *Santomerse D*, sodium decylbenzenesulfonate, per 5,000 cubic centimeters of distilled water. This gave the finished solution the desired wetting properties. Compounds which were insoluble in water were shaken until an emulsion or fine suspension was obtained. The emulsion or suspension was sprayed as quickly as possible, before it could break or settle in the spray container.

An atomizer-type, compressed air paint sprayer of one-pint capacity was used to spray the leaves at a pressure of 30 pounds per square inch. Both sides of the leaves were sprayed until a slight run-off was obtained.

Where two or more dilutions of a single material were desired, the higher dilutions were made from the lower; *i.e.*, 50 cc. of a 1 to 500 solution plus 50 cc. of the stock solution were mixed to give 100 cc. of 1 to 1,000 solution. Concentrations of solutions were made on a volume basis, except as otherwise noted.

The first work was done using *Tanglefoot* barriers to retain the aphids, but these barriers soon proved inefficient and also required considerable time for replacement for each series of tests. Efforts were made to find a chemical barrier more efficient than *Tanglefoot*, but a suitable one was not obtained until Bruce (1947)[1] of the Illinois State Natural History Survey became interested in the problem and developed a heated wire barrier which has been used for all work herein reported.

Mortality counts were made 24 hours after spraying. It was observed that for a number of compounds individuals were noticeably affected by the treatment applied but were not dead at the end of the 24-hour period. Therefore, those individuals which showed evidences of life (*i.e.*, capable of moving an antenna or a leg, or capable only of decidedly abnormal locomotion) were called "moribund." Preliminary tests with hexaethyl tetraphosphate showed that individuals counted moribund at 24 hours died by the end of 48 hours.

EXPERIMENTAL RESULTS.—It was believed that *Myzus persicae*, a species less resistant to insecticides than *Myzus porosus*, would show more clearly any differences between less effective compounds. Most of the compounds therefore were first tested against this species and, if high mortality was obtained, were tested against *M. porosus* at dilutions decreasing in strength until mortality fell off. A number of compounds known by previous exploratory tests to be very effective or thought to be very effective by consideration of structure were immediately tested against *M. porosus* without being tested against *M. persicae*. Two check tests, one of the wetting agent and one of 95 per cent nicotine alkaloid, were made with each series of tests.

Each dilution of a compound was replicated five times, and the average per cent mortality and the average per cent moribund individuals are reported in table 1.

[1] Unpublished Ms.

Table 1.—Toxicity of certain phosphorus acid esters to *Myzus persicae* and *M. porosus*.

Compound		Dilution	*Myzus persicae*		*Myzus porosus*	
			Per Cent Kill	Per Cent Moribund	Per Cent Kill	Per Cent Moribund
Alkyl Acid Phosphate Esters: $(HO)_2P(O)OR$ and $(HO)P(O)(OR)_2$[1]		1–500				
Methyl	$R=CH_3-$	"	51.4[2]	3.1		
Ethyl	$R=C_2H_5-$	"	37.8	6.6		
Propyl[3]	$R=C_3H_7-$	"	55.1	2.2		
Isopropyl	$R=(CH_3)_2CH-$	"	73.6	1.9	46.5[4]	3.2
Butyl	$R=C_4H_9-$	"	62.2	1.5		
Amyl	R = Mixed primary amyls	"	56.6	0.1		
Octyl	$R=C_8H_{17}-$	"	79.4	0.4	66.0	1.8
Loralkyl, (s)[5]	R = Mixture of 10 to 18 carbon chains	"	4.5	0.3		
Trialkyl and Triaryl Phosphate Esters: $P(O)(OR)_3$		"				
Trimethyl	$R=CH_3-$	"	52.2	5.7		
Triethyl	$R=C_2H_5-$	"	14.7	6.5		
Tri-(β-chloroethyl)	$R=ClCH_2CH_2-$	"	45.6	5.7		
Triallyl	$R=CH_2=CHCH_2-$	"	28.8	3.9		
Trimethallyl	$R=CH_2=C(CH_3)CH_2-$	"	33.9	3.6		
Tri-(2-ethylhexyl)	$R=CH_3(CH_2)_3CH(C_2H_5)CH_2-$	"	87.1	0.7	51.1	1.8
Triphenyl, (s)	$R=C_6H_5-$	"	21.2	4.3		
Tricresyl	$R=CH_3C_6H_4-$	"	20.3	3.9		
Tri-(o-chlorophenyl), (s)	$R=ClC_6H_4$	"	5.3	0.4		
Tri-(2,4,6-trichlorophenyl), (s)	$R=Cl_3C_6H_2-$	"	8.2	0.9		
Phosphonate Esters: $P(O)(R')(OR)_2$		"				
Diethyl trichloromethane-	$R=C_2H_5-$; $R'=CCl_3-$	"	28.1	1.0		
Diethyl p-chlorobenzene-	$R=C_2H_5-$; $R'=ClC_6H_4-$	"	55.0	5.6		
Diethyl 3,4-dichlorobenzene-	$R=C_2H_5-$; $R'=Cl_2C_6H_3-$	"	66.8	4.0		
Dibutyl trichloromethane-	$R=C_4H_9-$; $R'=CCl_3-$	"	24.3	0.6		
Dibutyl 2-propene-	$R=C_4H_9-$; $R'=CH_3=CHCH_2-$	"	70.9	4.2		
Dibutyl 2-methyl-2-propene-	$R=C_4H_9-$; $R'=CH_3=C(CH_3)CH_2-$	"	76.1	3.6		
Dibutyl β-styrene-	$R=C_4H_9-$; $R'=C_6H_5CH=CH-$	"	90.3	4.3	38.7	3.0
Di-(p-chlorophenyl)ethane-	$R=ClC_6H_4-$; $R'=C_2H_5-$	"	26.2	3.6		
Triethyl phosphonoacetate	$R=C_2H_5-$; $R'=C_2H_5OOCCH_2-$	"	55.4	1.8		
Dialkyl Phosphite Esters: $P(OH)(OR)_2$		"				
Diethyl	$R=CH_3-$	"	12.2	0.0		
Dibutyl	$R=C_4H_9-$	"	23.8	2.5		
Trialkyl Phosphite Esters: $P(OR)_3$		"				
Triethyl	$R=C_2H_5-$	"	13.7	0.0		
Tributyl	$R=C_4H_9-$	"	30.6	0.5		
Arylphosphonic Acids: $P(O)(OH)_2R$		"				
p-chlorobenzene-, (s)	$R=ClC_6H_4-$	"	6.1	3.4		
3,4-dichlorobenzene-, (s)	$R=Cl_2C_6H_3-$	"	4.8	1.2		
Phosphine Oxides: $P(O)R_3$		"				
Tri-(p-chlorophenyl), (s)	$R=ClC_6H_4-$	"	13.4	0.8		
Tri-(ethyl benzenephosphono)	$R=C_6H_5P(O)O(OC_2H_5)-$	"	94.6	1.7	59.0	2.8
Tetraalkyl Pyrophosphate Esters: $(RO)_2P(O)OP(O)(OR)_2$		"				
Tetraethyl	$R=C_2H_5$	1 to 10,000			95.4	1.8
		1 to 20,000			85.6	5.8
		1 to 40,000			52.7	6.8
Tetrapropyl	$R=C_3H_7-$	1 to 10,000			91.6	1.4
		1 to 20,000			75.4	3.4
		1 to 40,000			50.9	4.0
Tetrabutyl	$R=C_4H_9-$	1 to 5,000			91.2	1.2
		1 to 10,000			71.3	4.5
Tetraalkyl-Aryl Triphosphate Esters: $(RO)_2P(O)OP(O)(OC_6H_5)OP(O)(OR)_2$						
sym. Phenyl tetrapropyl	$R=C_3H_7-$	1 to 10,000			85.9	3.1
		1 to 20,000			66.4	14.5
sym. Tetrabutyl phenyl	$R=C_4H_9-$	1 to 2,000			94.3	2.9
		1 to 5,000			45.1	4.2
Hexaalkyl Tetraphosphate Esters: $P(O)[OP(O)(OR)_2]_3$						
Hexaethyl	$R=C_2H_5-$	1 to 5,000			88.8	3.6
		1 to 10,000			63.4	6.0
Hexapropyl	$R=C_3H_7-$	1 to 2,000			99.0	0.4
		1 to 4,000			79.8	4.3
Hexabutyl	$R=C_4H_9-$	1 to 5,000			89.3	1.6
		1 to 10,000			66.2	5.0
Hexa-(2-ethylhexyl)		1 to 500	89.7	1.3	67.8	2.0
		1 to 1,000			45.9	2.3
Miscellaneous Compounds						
Poly-(dibutoxyphosphonitrile)	$[(C_4H_9O)_2P\equiv N]_x$	1 to 500	48.7	2.1		
Tetraphenyl diethyleneglycol diphosphate	$[P(O)(OC_6H_5)_2(OC_2H_4)]_2O$	1 to 500	33.8	1.3		
Santomerse "D," Sodium decylbenzenesulfonate, Wetting Agent		1 to 5,000	4.3	1.4	6.7	2.5
Nicotine, 95% free base		1 to 2,000	75.2	13.3	48.8	4.4

[1] These compounds are commercial products containing a constant ratio of the di- to the monoester.
[2] A difference of 23.6% in mean mortalities is required for significance at the 5% level between the compounds tested against *M. persicae*.
[3] Aliphatic chains are of the normal configuration unless otherwise indicated.
[4] Differences of 14.9%, 16.0%, and 23.3% in mean mortalities are required for significance at the 5% level for dilutions of 1 to 5,000, 1 to 10,000, and 1 to 20,000, respectively, between the compounds tested against *M. porosus*.
[5] (s) indicates that the compound is a solid.

DISCUSSION.—In general, it is difficult to characterize and identify the polyphosphate esters chemically. Consequently, several of the chemicals reported may be mixtures, impure compounds, or compositions, rather than definite chemical entities. The structure of hexaethyl tetraphosphate has not been completely determined as yet, but it is believed to be $P(O)[OP(O)(OR)_2]_3$. It may be a straight chain molecule, however. The terms "nucleus" and "acid nucleus" will be used in the following discussion to designate that portion of a molecule which contains phosphorus.

TOXICITY DUE TO THE PHOSPHORUS NUCLEI.—Analogous series of the several phosphorus nuclei are too incomplete to permit a valid differentiation of toxicity due to various nuclei. However, the simple phosphorus compounds, including the acid phosphate, phosphate, phosphonate, phosphite, phosphonic acid, and the phosphine oxide derivatives, are inferior in toxicity to nicotine. The polyphosphate compounds, including the pyrophosphate, triphosphate, and the tetraphosphate derivatives, on the other hand, are more highly toxic than nicotine.

EFFECTS OF SUBSTITUTION OF VARIOUS INDIVIDUAL PHOSPHORUS NUCLEI UPON TOXICITY.—*Phosphate esters:* Substitution of triallyl-, -methallyl-, -phenyl-, -cresyl-, -*o*-chlorophenyl,- or -(2, 4, 6-trichlorophenyl)- for triethyl- has no significant effect upon the toxicity of the nucleus. Substitution of tri -(β-chloroethyl)- and trimethyl for triethyl gives a significant increase in toxicity. Tri-(2-ethylhexyl) phosphate is significantly more toxic than the preceding two compounds mentioned above and is the most toxic compound studied in the phosphate series, but it is definitely inferior to nicotine.

Acid phosphate esters: Ethyl- is significantly better than loralkyl acid phosphate; but, in general, increased length of the carbon chain tends to increase the toxicity of the nucleus. Methyl-, propyl-, and amyl- are not significantly more toxic than ethyl-; but butyl-, isopropyl-, and octyl-, though not significantly different among themselves, are significantly more toxic than ethyl acid phosphate.

Phosphonate esters: Dibutyl trichloromethane-, di-(*p*-chlorophenyl) ethane-, and diethyl trichloromethane- are significantly less toxic than triethyl phosphonoacetate; while diethyl *p*-chlorobenzene-, diethyl 3, 4-dichlorobenzene-, dibutyl 2-propene- and dibutyl 2-methyl-2-propene- are of the same significant toxicity as triethyl phosphonoacetate. Dibutyl β-styrenephosphonate is the only outstanding member of this series and even it does not compare favorably with nicotine.

This series of compounds injured foliage considerably, the injury being caused mainly by the molecules containing unsaturated carbon-carbon linkages. The phosphate series caused no injury, despite the fact that several of the molecules contained similar unsaturated linkages.

SUMMARY AND CONCLUSIONS.—Forty-six chemical compounds, organic derivatives of phosphorus acids, were tested as contact insecticides for toxicity to the green peach aphid, *Myzus persicae* Sulzer, and to an aphid infesting greenhouse-grown rose plants, *Myzus porosus* Sanderson. The compounds were evaluated from mortalities of water solutions sprayed on infested leaves.

The experiments reported lead to the following conclusions: 1. Eight of the compounds tested, including hexaethyl tetraphosphate, are superior in toxicity to nicotine alkaloid. The most promising of these are tetraethyl pyrophosphate, tetrapropyl pyrophosphate, and *sym.* tetrapropyl phenyl triphosphate, which may all possess commercial possibilities.

2. The pyrophosphates and triphosphates are extremely toxic to aphids.

3. *Myzus porosus* is more resistant to the compounds tested than *M. persicae.*

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A Comparison of Rotenone, DDT, and Benzene Hexachloride for Pea Aphid Control[1]

H. F. Wilson, W. B. Hull, and A. S. Srivastava[2]

During the winter of 1945–46 comparative greenhouse tests were made at Madison, Wisconsin with different concentrations of DDT and benzene hexachloride against the pea aphid. These two chemicals were then compared in field tests during the summer of 1946. Results from the greenhouse studies are shown in table 1 and data from field studies are presented in tables 2 and 3.

Greenhouse Tests.—Using the laboratory technique previously reported (Dieter *et al.* 1944) a large series of comparative tests were carried on in the greenhouse which showed that the technical grade of DDT was definitely superior to benzene hexachloride. The results are shown in table 1. All dosages were at the rate of 200 mgs. of dust per treatment.

Table 1.—Comparative control data with different concentrations of DDT and benzene hexachloride with and without added oil.

	Per Cent Control		
	24 hrs.	48 hrs.	72 hrs.
DDT 1%	47	84	87
DDT 2%	54	86	91
DDT 3%	77	87	91
DDT 4%	85	92	97
DDT 5%	93	97	97
DDT 1%+3% oil[1]	93	100	100
DDT 2%+3% oil	94	100	100
DDT 3%+3% oil	92	100	100
DDT 4%+3% oil	100	—	100
DDT 5%+3% oil	100	—	100
DDT 1%+0.25% rotenone, 3% oil	100	—	100
DDT 2%+0.25% rotenone, 3% oil	100	—	100
BHC 1%	15	26	50
BHC 2%	19	61	69
BHC 3%	31	45	73
BHC 4%	45	75	82
BHC 5%	65	86	88
BHC 1%+3% oil[1]	24	45	72
BHC 2%+3% oil	43	83	88
BHC 3%+3% oil	57	82	90
BHC 4%+3% oil	74	88	93
BHC 5%+3% oil	84	93	100
BHC 1%+0.25% rotenone, +3% oil	48	80	93
BHC 2%+0.25% rotenone, +3% oil	76	90	93

[1] The oil used in these tests was a mixture of equal parts of SAE10 lubricating oil and propylene laurate.

Field Tests.—The 1946 season was generally favorable for pea aphid development and a heavy infestation developed throughout the southern part of Wisconsin. Because of light rainfall in April, May, and June, the infestation was persistent and did not start to decline until late June in some areas, and not until after July 1 in others. Predators developed slowly and aphids attacked by fungus were not noticed in the experimental fields until June 23 when a few diseased aphids were found on the stems and leaves, By June there was a distinct increase in the number of fungus infected aphids.

Five separate field experiments were made in 1946 to compare the toxic values of DDT and benzene hexachloride for control of the pea aphid. Two were made on small plots with a hand duster and three on large field plots with a ground duster. The two principal field tests are reported and show clearly the trends indicated for the entire series.

Table 2.—Average per cent control with five replicated plots of 3 per cent DDT and seven replicated plots of 3 per cent benzene hexachloride. Dust applied at approximately 25 pounds per acre. June 13, 1946.

	June 16		June 19	
Material	Ave. Aphids per Sweep	Per Cent Control	Ave. Aphids per Sweep	Per Cent Control
DDT 3%	43	88	40	89
Benzene hexachloride 3%	92	73	61	83
Check area	350		350	

	June 21		June 23 and 26	
Material	Ave. Aphids per Sweep	Per Cent Control	Ave. Aphids per Sweep	Per Cent Control
DDT 3%	68	81	61	82
Benzene hexachloride 3%	193	45	213	38
Check area	350		350	

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[1] Contribution from Wisc. Agr. Expt. Sta. authorized for publication by the Director.
[2] Professor and graduate students respectively in the Department of Economic Entomology.

Experiment 1 was set up to compare 3 per cent concentrations of DDT and benzene hexachloride in *Pyrax* and conditioned with a series of heavy oil solvents. The differences between solvents were not significant. The other data are shown in table 2.

EXPERIMENT 2.—June 13, 1946. Time of application 6 to 8 P.M. with a wind speed of 3 m.p.h. Temperature 60° F. with a low of 45° at night. This was followed by rising temperatures up to 88° F. on June 16. Dust applied at a near average rate of 40 pounds per acre on Prince of Wales type peas. The data is based on six sweeps in eight replicated plots of two each in four different plantings. These were developed by applying each material twice across each planting with an 18 nozzle *Niagara Dri-Fog* machine covering 25 feet per swath. Three check areas were used across the field, one in the center and one at each end. The treatments were to be made on June 8 when the aphid population averaged near 50 per sweep for the field, but due to a lack of a team until June 10, and a heavy rain, the applications could not be made until June 13. By that time the population had increased to 150 to 200 per sweep. By June 16 the population in the checks had risen from 350 to 1000 per sweep and remained at that level until June 24 and 25 when one check was so badly damaged that the lice began to leave and move into adjoining treated plots in a third experiment not reported. By July 1 all the check areas showed considerable damage and the heavily infested check was hardly worth harvesting.

The lower count for the check areas on June 26 was attributed in part to aphid migration in one of the check areas but both predators and fungus were abundant enough to cause a noticeable decrease in population.

A common practice followed by Wisconsin canners in planting large fields is to plant from 4 to 6 acres per day at 2 to 3 day intervals. If dusting is necessary, a whole field, regardless of planting dates, is usually treated. To make the experiment comparable with general field conditions, four continuous plantings were used.

Date of planting and height of vines at the time of treating. June 13, 1946.

PLANTING	ACRES	DATE	VINE HEIGHT
No. 1	5	April 19	12 to 14 in. full blossom
No. 2	4	April 22	10 to 12 in. a few blossoms
No. 3	6	April 24	10 to 12 in. no blossoms
No. 4	6.5	April 26	8 to 10 in.

The assembled data is shown in table 3.

CONCLUSIONS.—Under greenhouse conditions DDT was shown to be more effective than benzene hexachloride at all concentrations both with and without added

Table 3.—Per cent control of the pea aphid obtained using variable concentrations of DDT and BHC alone and conditioned with oil solvents and, in combination with rotenone. June 13, 1946.

	MATERIALS (PER CENT)						JUNE 16 & 17		JUNE 23		JUNE 26	
No.	Rotenone	DDT	BHC	Oil Solvent	Dispersant	No. REPLICATED PLOTS	Avg. Aphids per Sweep	Per Cent Control	Avg. Aphids per Sweep	Per Cent Control	Avg. Aphids per Sweep	Per Cent Control
1	0.75			2[1]	Pyrax	8	60	89	56	90	85	75
2[4]	0.25					8	92	83	142	74	97	73
3	0.5	1.0		3[1]	Pyrax	8	45	92	19	97	30	92
4	0.25	2.0		3[1]	Pyrax	8	42	92	26	95	20	94
5		2.5		2[2]	Pyrax	8	54	90	34	92	38	89
6		2.5		2[3]	Pyrax	8	44	92	20	96	46	87
7		3.0		3[1]	Pyrax	8	52	91	21	96	46	87
8		3.0		3[1]	Talc	8	46	92	—	—	28	92
9	0.25		2	3[1]	Pyrax	8	65	88	53	90	98	72
10			5	2[2]	Pyrax	8	52	91	45	91	56	84
11			5	2[3]	Pyrax	8	84	85	70	87	117	67
12[4]	0.25	2.0				4	45	92	29	94	—	—
13		5.0			Pyrax	4	69	88	24	96	—	—
Checks							550		550		350	

Average number of aphids per sweep required for significant difference June 16 and 17, 17.
[1] One-half propylene laurate and one-half SAE10 lubricating oil.
[2] Yarmor pine oil.
[3] D.H.S. activator.
[4] Commercial preparation—"Agicide."

oil. When oil was added both chemicals became more effective but 1 per cent DDT was as effective as 5 per cent benzene hexachloride. When combinations of 0.25 per cent rotenone and 1 to 2 per cent DDT or benzene hexachloride were used, there was a slight indication of synergism. However, 1 and 2 per cent DDT were little affected by the addition of rotenone.

The 1946 field data indicate that 2.5 to 3 per cent DDT with an oil solvent may be as effective as 5 per cent DDT in a dry mixed dust, and that a 0.75 per cent rotenone dust applied during a period of high temperatures appeared about equal to the DDT dusting during the first week after the treatments were applied. At the time of harvest a few injured pods were found in the plots treated with 0.75 per cent rotenone. None could be observed in any of the DDT plots.

In comparison with rotenone and benzene hexachloride, DDT appeared to have a greater residual effect. Benzene hexachloride was about as effective as DDT in one field test but, obviously, higher concentrations of benzene hexachloride than of DDT will be required for effective pea aphid control. Combined low concentrations of rotenone and DDT gave high control but were not more effective than 2.5 and 3 per cent DDT alone.—12-12-46.

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Further Tests for Control of Mexican Bean Beetle and Corn Earworm on Snap Beans[1]

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A previous report (Brannon 1945) gives the results of experiments conducted on fall-crop snap beans for the control of the Mexican bean beetle, *Epilachna varivestis* Muls., and the corn earworm, *Heliothis armigera* Hbn., in the presence of powdery mildew disease, *Erysiphe polygoni* DC. Cryolite is shown to be superior to rotenone for the combined control of the two insects, and sulfur to be preferable to talc or other diluents for this insecticide owing to its value against mildew. Rotenone is shown to be ineffective against the corn earworm though highly effective against the Mexican bean beetle. Other experiments conducted by the writer in 1944 and 1945 (unpublished) show that, conversely, although dust mixtures containing DDT at concentrations as high as 10 per cent are very effective against the corn earworm on beans, they are ineffective against the Mexican bean beetle. DDT is known to be toxic to such associated insect pests of beans as the potato leafhopper, *Empoasca fabae* Harr. (Howard 1944), White 1946), and the onion thrips, *Thrips tabaci* Lind (Smith 1944; Chapman *et al.* 1945), pests which are not controlled with cryolite or rotenone.

With these results as a background, experiments were undertaken to determine the comparative effectiveness of combinations of DDT and rotenone, a methoxy analog of DDT (di-(*p*-methoxyphenyl) trichloroethane), and other materials as all-purpose insecticides, cryolite being used as the standard for comparison. Owing to its previously demonstrated effectiveness against mildew, from 20 to 50 per cent of sulfur was incorporated in the diluents of all except one of the dust mixtures tested.

PROCEDURE.—Two experiments were conducted on Bountiful snap beans at Norfolk, Va., in the fall of 1946. Plots containing four rows 80 feet long and 3 feet apart were used. The plots for the various treatments were randomized in four blocks, so that each treatment occurred once within each block. Each block also contained one undusted plot.

The dusts were applied with a 4-row power duster equipped with two "scoop" nozzles to each row, of the type used against bean beetles, and with a light cloth trailer extending approximately 12 feet to

[1] Paper presented at the Richmond Meeting, Dec. 1946.
[2] In cooperation with the Virginia Truck Experiment Station.

the rear. The aerosol tested in experiment 2 was applied by hand by use of an adjustable extension pipe fitted with an oil-burner nozzle of 1.5 gallon-per-hour capacity attached to the aerosol cylinder. The beans were treated from each side of the row, so that the under surface of the foliage was covered.

Commercial materials used in preparing the dust mixtures were synthetic cryolite (sodium fluoaluminate 92.6 per cent), cube root powder (rotenone 3.7 per cent, total extractives 13.7 per cent), 50 per cent benzene hexachloride (gamma isomer 5 per cent), 49.1 per cent DDT, and 50 per cent methoxy analog of DDT. A commercial mixture of pyrethrum and "piperonyl cyclohexenone" was tested without further dilution. The aerosol[1] contained 3 per cent of derris resins, 10 per cent of isophorone, 3 per cent of lubricating oil, 31 per cent of acetone, and 50 per cent of methyl chloride.

Experiment 1.—Applications of the various dusts were made on August 26 and September 9. No rain fell between the first and second applications; however, 0.3 inch fell 48 hours after the second application, and an additional 0.18 inch 24 hours later. At the time of the first application the plants were budding, and at the time of the second they were in bloom and beginning to form small pods. Counts of Mexican bean beetles made on the 4 random undusted plots 3 days prior to the first application indicated an average infestation of 4.7 beetles, 2.5 egg masses, and 1.5 batches of young larvae on 6 feet of row. The white fungus causing powdery mildew was first observed on the foliage at this time. It spread rapidly and caused considerable damage to both foliage and pods, damage to the latter being especially noticeable at the time of the second picking.

The first corn earworm eggs were found on the leaves on August 21, three eggs being found on 25 plants selected at random in the field. At this time the plants were budding, no blooms having been observed. The beans were picked on September 20 and 30.

Experiment 2.—Applications of insecticides were made on September 9 and 23. Within 48 hours after the first application 0.3 inch of rain fell, and an additional 0.18 inch fell 24 hours later. Rainfall amounting to 1.02 inches occurred 30 hours after the second application. At the time of the first application the plants contained several sets of trifoliate leaves, and at the time of the second the plants were blooming and beginning to form small pods. Counts of bean beetles made on the 4 random untreated plots 5 days prior to the first application indicated an average infestation of 3.7 beetles, 5.7 egg masses, 1.1 newly hatched egg masses, and 0.5 batch of young larvae on 6 feet of row. The white fungus causing powdery mildew was first observed on the foliage on August 29. As in experiment 1, it spread rapidly and caused severe damage to both foliage and pods.

The first earworm eggs were found on the leaves on August 21, two eggs being found on 25 plants taken at random in the field. At this time the plants contained only their two cotyledonous leaves. Similar examinations made on September 4 disclosed no earworm eggs, although 3 larvae a half-inch long were found. At the time of the second application several larvae from 0.75 inch to 1.5 inches long were observed feeding on the foliage and boring into blossoms and developing pods. The beans were picked on October 4 and 15.

RESULTS.—The results of the experiments are presented in table 1. Under conditions of unusually heavy infestations of the Mexican bean beetle and corn earworm, and widespread prevalence of powdery mildew disease, two applications of a dust mixture containing either 1 or 3 per cent of DDT, 0.50 per cent of rotenone, and 50 per cent of sulfur are as effective as cryolite-sulfur (sodium fluoaluminate 72 per cent) or any insecticide yet tested for simultaneous control of the two insects and the disease. Increases ranging from 57 to 99 bushels of marketable beans per acre over yields from undusted plots were obtained. Benzene hexachloride (3 per cent of gamma isomer) gave significant control of the earworm, but was not so effective as either DDT-rotenone or cryolite, and was relatively ineffective against the Mexican bean beetle. A commercial pyrethrum-"piperonyl cyclohexenone" dust mixture gave significant control of both the earworm and the bean beetle, but was inferior to the DDT-rotenone and cryolite dusts. This dust mixture proved more effective against both species of insects than previously tested pyrethrum dusts containing from 0.50 to 1.0 per cent

[1] Prepared by R. A. Fulton, of the Division of Insecticide Investigations, Bureau of Entomology and Plant Quarantine.

Table 1.—**Effectiveness of various insecticide dusts and DDT-rotenone aerosol against the Mexican bean beetle and the corn earworm on snap beans.**

Formulations (Per Cent by Weight)	Rate per Acre	Experiment 1			Experiment 2		
		Marketable Beans per Acre	Wormy Pods per Plot	Bean Beetle Larvae and Pupae Surviving on 10 Plants[1]	Marketable Beans per Acre	Wormy Pods per Plot	Bean Beetle Larvae and Pupae Surviving on 10 Plants[2]
	Pounds	*Bushels*	*Per Cent*	*Number*	*Bushels*	*Per Cent*	*Number*
Dusts (in pyrophyllite):							
DDT 3+rotenone 0.5+sulfur 50	25	164	0.3	2	100	0.4	2
DDT 1+rotenone 0.5+sulfur 50	26	157	0.9	1	87	2.2	1
Cryolite (sodium fluoaluminate 72)+sulfur 22	29	173	2.0	7	88	1.3	20
Benzene hexachloride (gamma isomer) 3+sulfur 20	30	137	4.6	63	—	—	—
Methoxy analog of DDT 5+sulfur 50	25	—	—	—	88	5.1	5
Pyrethrum (pyrethrins 0.04) "piperonyl cyclohexenone" 0.5	29	128	7.5	34	66	9.7	7
Aerosol: DDT 3, derris resin 3	6	—	—	—	37	4.6	139
Untreated check	—	65	24.0	122	30	28.6	148
Difference required for significance (P=0.05)		34	5.9	14	19	6.9	30

[1] Records taken 10 days after second application.
[2] Records taken 8 days after second application.

of pyrethrins but without the addition of "piperonyl cyclohexenone." Since the mixture gave significant control of both the bean beetle and the earworm, the comparatively small increase in yield resulting from its application may be due partly to its failure to protect the plants against powdery mildew. This was the only insecticide tested in which sulfur was not included. At the conclusion of the experiment the foliage of the plants on the undusted plots and on plots treated with pyrethrum-"piperonyl cyclohexenone" was covered with the white fungus causing powdery mildew disease, whereas plants in plots that had received treatments containing from 20 to 50 per cent of sulfur remained green and healthy. Many of the pods on plants that did not receive sulfur were unmarketable, being dwarfed, deformed, and badly spotted with reddish, brown lesions owing to injury from the disease. This damage was especially noticeable at the time of the second picking.

The results of experiment 2 corroborate those of experiment 1 with regard to the comparative effectiveness of DDT-rotenone, cryolite, and pyrethrum-"piperonyl cyclohexenone" for the combined control of Mexican bean beetle, corn earworm, and powdery mildew. Experiment 2 shows further that the methoxy analog of DDT plus sulfur gave control of the bean beetle and the earworm comparable to that obtained with either the DDT-rotenone dusts or cryolite. During 1945 tests with dust mixtures containing 10 per cent of the methoxy analog of DDT showed that the material was effective against the bean beetle but not against the earworm. The material used in 1945 contained 5 per cent of diatomaceous earth and 85 per cent of talc, while that used in 1946 contained 5 per cent of clay, 50 per cent of sulfur and 40 per cent of pyrophyllite. It appears that differences in the diluents used in the preparation of the two dust mixtures may have been at least partly responsible for the difference in toxicity to the earworm.

An aerosol containing 3 per cent of DDT and 3 per cent of rotenone, applied at the rate of 6 pounds per acre, gave significant control of the earworm but proved ineffective against the bean beetle. Since a rotenone aerosol (5 per cent) applied earlier in the season against the bean beetle alone at rates of 10 to 15 pounds per acre gave approximately 60 per cent control, the ineffectiveness of the DDT-rotenone aerosol against the bean beetle in the present test no doubt may be attributed largely to the low dosage of the rotenone. Since both applications were made by hand at approximately the same speed and with the same type of nozzle, differences in the formulation, and consequently in particle size, may have been responsible for the low dosage of the DDT-rotenone aerosol compared with the rotenone aerosol alone. In view of the low dosage, it is surprising that the DDT con-

tained in this dual-purpose aerosol—0.18 pound per acre compared with 0.75 pound in the case of DDT-rotenone dust mixture —gave significant control of the corn earworm.

Table 1 shows that, as has been found in the past, a 0.50 per cent rotenone dust is highly effective against the Mexican bean beetle. Moreover, the preparation of synthetic cryolite used in the experimental work reported herein gave better control of the bean beetle than was obtained in many previous tests.

No stunting or injury to bean foliage, attributable to DDT, was observed in either experiment where the 3 per cent concentrations were applied on snap beans, nor has injury been observed in tests made in 1944 and 1945 on both snap and lima beans where a maximum concentration of 10 per cent DDT was applied.

SUMMARY AND CONCLUSIONS.—Results of two large-plot field experiments conducted at Norfolk, Va., in 1946 on fall-crop snap beans under conditions of unusually heavy infestations of the Mexican bean beetle and corn earworm, and widespread prevalence of powdery mildew disease, show that two applications of a dust mixture containing either 1 or 3 per cent of DDT, 0.50 per cent of rotenone, and 50 per cent of sulfur are as effective as two applications of cryolite-sulfur (72 per cent sodium fluoaluminate), previously recommended, or any insecticide yet tested for simultaneous control of the two insects and the disease. The application of the DDT-rotenone-sulfur dust resulted in yield increases ranging from 57 to 99 bushels of marketable beans per acre over those from undusted plots. Since DDT is known to be superior to cryolite against the potato leafhopper and onion thrips, the DDT-rotenone-sulfur dusts reported herein may prove of value as all-purpose insecticides on fall-crop snap beans in eastern Virginia.

Benzene hexachloride (3 per cent of the gamma isomer) gave control of the corn earworm but was not so effective as either DDT-rotenone or cryolite, and was relatively ineffective against the bean beetle. A commercial pyrethrum-"piperonyl cyclohexenone" dust controlled both the earworm and the bean beetle, but was inferior to the DDT-rotenone and cryolite dust mixtures. Dusts containing 5 or 10 per cent of a methoxy analog of DDT controlled the bean beetle, but gave variable results against the earworm. A DDT-rotenone aerosol applied at the rate of 6 pounds per acre controlled the earworm, but was ineffective against the bean beetle, owing possibly to the low dosage of rotenone.

These investigations, as well as work conducted during preceding years against the corn earworm on snap beans, have indicated that two insecticide applications, the first about 2 weeks prior to blooming and the second when the crop is in full bloom, under usual conditions may be expected to provide adequate protection against these pests. Insecticides applied before the pods form should not leave harmful residues on the market product.

Owing to the extreme difficulty in finding appreciable numbers of eggs and small larvae of the earworm, and the potentially heavy damage which may result from this relatively small population, it has been found advisable in eastern Virginia to apply insecticides on fall beans as insurance against damage by this pest. Since the DDT-rotenone-sulfur dust mixture is also effective against the Mexican bean beetle, and the various kinds of loopers usually present on fall-crop beans, and is of value against powdery mildew, this treatment is often practicable.—12-12-46.

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Some Relationships of Insects to Net Necrosis of the Potato in Colorado[1,2,3]

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Net necrosis of the potato has been common in Colorado for a number of years. It has been more prevalent in home gardens and plantings of small acreages. During some seasons locally grown potatoes are definitely discriminated against by the housewife. In 1944 losses in commercial fields were heavy and few fields being grown for seed certification were entirely free. That year certification was refused for the tubers from over 300 acres because of net necrosis showing at the time of bin inspection.

During the past six seasons the writer has conducted experimental tests for the control of the potato psyllid, *Paratrioza cockerelli* (Sulc) and the tuber flea beetle, *Epitrix turberis* Gentner. During part of this time studies were also under way on aster yellows and the possible occurrence of aster yellows in celery and head lettuce. Much of the data here presented on the relationship of insects to net necrosis of the potato came only indirectly from these experiments. The results seem worthy of publication in light of the recent findings of Leach & Bishop (1946) that a condition which they designate as purple-top wilt, or blue stem of potatoes and which is accompanied by net necrosis of the tuber is transmitted by the six-spotted leafhopper *Macrosteles divisus* (Uhl.) and is probably caused by the aster-yellows virus, *Chlorogenus callistephi* Holmes. In addition, there has been rather a general feeling in Colorado that in some way the potato psyllid is responsible for tuber net necrosis.

TUBER AND VINE SYMPTOMS.—Necrosis in the tuber may vary from slight stem-end browning to a definite breaking down of small areas of the tissue throughout the storage parenchyma. Since the stem-end browning does not seem to be constant, the term net necrosis as used here applies to those cases where the condition extends into the inner phloem. Such tubers, especially in the white varieties, have a dull-colored, lifeless skin. When cut into they are found to be hard and brittle. They remain firm until late in the spring and can often be sorted from stored stock by this characteristics. If a considerable portion of the tuber is involved the eyes fail to grow. Less severely affected tubers produce weak sprouts. Necrotic tubers are lower in specific gravity than normal ones and when planted may not decay for months.

The vine symptoms of plants found to carry necrotic tubers are, for the most part, those that result from faulty translocation of elaborated plant food. The time of infection apparently has an effect upon symptom expression; however, few clear symptoms appear until late in the season. The terminal growth is checked, internodes are shortened, and the leaflets fail to expand normally and their edges, especially near the base, roll upward. The leaves show abnormal pigmentation. This may vary from pale yellow to a purplish color. The purple is most pronounced in the red varieties. The stems may also take on the purple discoloration. Under some conditions starch may be stored at the base of leaves and shoots, thus forming enlarged nodes or axillary tubers. All of these expressions may be found in different degrees in plants infected with *Rhizoctonia*, *Fusarium* wilt, hay wire, curly top, and psyllid yellows. The psyllid yellows, which is also spoken of by many Colorado growers as purple top, may so completely hide the symptoms that there has been a common opinion that late psyllid infestations were responsible for the tuber net necrosis. If any one of the symptom expressions mentioned is more specific than the others, it is the discoloration of the stems. This was especially noticeable in the fall of 1944 after the vines had been frosted. However, in the plots where the psyllids had not been controlled this character was of little value in selecting plants that would show tuber net necrosis. In

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[2] Acknowledgment is due Mrs. Nellie Landblom, for assistance in making statistical analysis of the data presented; to Edward Sylvester for assistance with field work during the seasons of 1941 and 1944 and to Dr. Arthur Moinat for assistance during 1945.

[3] Presented on the Richmond Program, Dec. 1947.

some cases a wilting of the leaves has been noted, but this has not been constant. In fact, the affected plants, as with psyllid yellows, hold up longer than do normal plants.

MATERIALS AND METHODS.—Potatoes do not grow normally in closed cages. Unpublished data secured in protecting small plots of asters against the six-spotted leafhopper by means of an aster cloth fence are mentioned here as a support of the method used in protecting potatoes against leafhoppers. The fences were usually 3 feet high and enclosed an area 6 feet square. In the field experiments for the control of the potato psyllid and the tuber flea beetle from which the data on net necrosis were taken each randomized plot consisted of six or eight rows. The length of the rows varied during the different years from 30 to 55 feet and replications varied from six to eight. The center four rows of each plot were harvested for the records. During the first 3 years the dusts were applied with a rotary hand operated duster and the sprays by means of a three-nozzle portable spray boom connected by a high pressure hose to a power sprayer which was driven between the blocks. During the last three seasons the sprays were applied with a four-row power sprayer which was driven through the plots and the dusts were applied by means of a four-row power dusters with two outlets per row. The sprays were applied at the rate of approximately 125 gallons per acre. A weighed amount of dust was applied to each plot. The rate of application varied with the different treatments from 20 to 30 pounds per acre. In a psyllid control test made in a greenhouse in the spring of 1944, six staked plants grown in 10-inch pots and trimmed to a single stem were used for each treatment. These were placed in randomized positions and removed for treatment applications. The sprays and dusts were applied by means of an electrically driven machine. The lime sulfur used in psyllid control was for the most part the standard liquid, testing not less than 32° Baume. During 2 years dry lime sulfur was compared with the liquid. The DDT used in making oil solutions which were applied as emulsions was of technical grade. The DDT dusts were prepared by reducing 40 and 50 per cent dust concentrates and mixing with the various diluents in a small ball-mill type of mixer. The wettable DDT powder used in preparing sprays during 1944 was a 20 per cent commercially prepared product, and for 1945 and 1946 a 50 per cent concentrate.

PROTECTING ASTERS AGAINST THE SIX-SPOTTED LEAFHOPPER.—The first tests of aster cloth fences to protect asters were made in my home garden in an effort to protect small ornamental plantings. Cages 6 feet square and 3 feet high were used. In 1938 and 1939 two such cages each year gave 100 per cent protection, while uncaged plants were 82 per cent infected in 1938 and 52.06 per cent in 1939.

During the season of 1941 aster cloth fence cages were used to study the aster yellows in asters, head lettuce and celery. Each cage was 4 feet wide, 8 feet long, and 3 feet high. Seven aster plants which were used as indicators, and from 10 to 16 lettuce plants were grown in each cage. The lettuce plants were permitted to produce seed to make more certain the reading of aster yellows. Seed-producing lettuce plants were growing near the cages. The lettuce had been drilled in rows and the plants were just large enough to be thinned on June 1 when the greenhouse-grown aster plants were set and the fence cages put into place. There was a total of 60 plots arranged in 4 blocks permitting 4 randomized replications. Eight cages were used in each block. On June 15 and the 1st and 15th of each month thereafter until September 15 one cage in each block was removed and the plots left unprotected the remainder of the season. This cage was placed on a previously unprotected plot where it remained throughout the aster blooming season. In each block one plot was caged and another was unprotected throughout the season.

Figure 1 shows the time of caging and time of exposure under each treatment and at the right is given the mean number of uninfected aster blossoms produced. Twenty-one, 19 and 17 late blossoms that showed symptoms of aster yellows were cut from treatments 9, 2 and 10 respectively. A complete record of diseased blossoms under the other treatments is of little value, since many plants showing early infection did not make a normal growth. The tall seeding lettuce growing in the fence-cages and also near by probably induced some movement of leafhoppers over the top of the cages.

Also, it is likely that some viruliferous leafhoppers were on the plants when some of the cages were placed. It will be noted that the fence type of cage when in place throughout the season and also from June 1 to September 15 and from June 15 to the end of the season gave almost complete protection. Caging during the forepart of the season was more important than during the latter.

GREENHOUSE TESTS WITH PSYLLIDS.—A greenhouse test conducted during the winter of 1943–44 for the control of the potato psyllid failed to show net necrosis resulting from varying degrees of psyllid infestation. Nine treatments with six replications were used. All plants were constantly exposed to psyllids moving from heavily infested potato and tomato plants in the center of the house. Table 1 gives the treatments, yields, psyllid population records, and the ratings on the degree of psyllid yellows injury. The population records were taken by counting all nymphs on 5 leaflets selected 3 times during the season from each plant by systematic random sampling. The rating for psyllid yellows was based on 1 for a trace and 50 for very severe, no tubers expected. The three readings were made independently on the same day near the end of the growing seasons by an entomologist, a plant pathologist and a horticulturist. It will be seen that there was a wide range among treatments in the degree of psyllid infestation and psyllid effect as shown by the psyllid yellows and the reduced tuber yield. All tubers were cut shortly after harvest and no indications of necrosis were found.

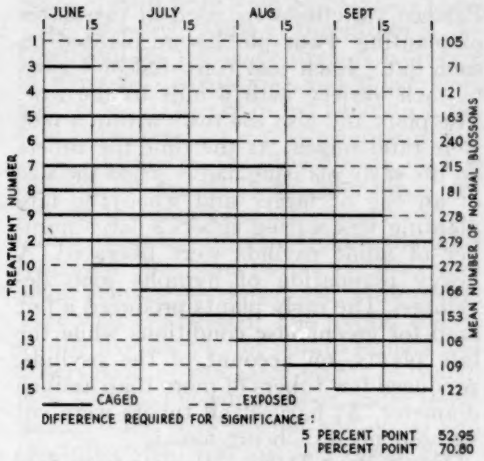

FIG. 1.—The effects of an aster cloth fence upon the number of aster blossoms free from aster yellows symptoms.

Net necrosis was probably more common during 1944 than ever before. Also psyllid infestations were heavy. This, along with the similarity of the vine symptoms associated with net necrosis and psyllid yellows, threw more suspicion upon the psyllid. An idea developed that possibly a late infestation of psyllids was responsible for the necrosis. During the winter of 1944–45 a test with psyllids was conducted in the greenhouses at the Greeley Potato Station.[1] Katahdin and

[1] In cooperation with W. C. Edmundson, Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry U.S. Department of Agriculture.

Table 1.—Potato psyllid control experiment in greenhouse, winter 1943-1944.

TREATMENT	MEAN YIELD PER PLANT, GRAMS	MEAN NO. PSYLLID NYMPHS PER 15 LEALFETS	AVERAGE PSYLLID YELLOWS RATING		
			Geo. M. List	W. A. Kreutzer	John McLean
Check. No treatment	2	1176.6	25	38	28
Lime sulfur 2.5 gallons, water 100 gallons	110.8	2.5	10	17	12
Wettable sulfur 10 lbs., water 100 gallons	49.6	56.6	16	31	24
Barium polysulfide 5 lbs., water 100 gallons	21.9	76.8	14	31	24
Dusting sulfur	120.9	0.5	6	12	10
DDT 1 lb. (5 lbs. 20% commercial product), water 100 gallons	239.1	6.5	6	10	8
DDT 0.4 lbs. (2 lbs. 20% commercial product), water 100 gallons	173.8	9.1	10	13	11
DDT dust—3% in inert carrier	211.9	0.1	1	4	2
DDT 1%, inert carrier 33.3% dusting sulfur 66.67%	163.6	6.1	2	7	5
Difference required for significance:					
5% point	44.6	23.88			
1% point		31.85			

Pawnee varieties were used in two dates of planting. Four plots were planted on each date. Each plot consisted of 4 rows of each variety with 6 hills to the row. The plots and also the rows within a plot were randomized. At the time the tubers on the early planting had reached the size of an egg or larger and when the late planting was setting tubers a large number of adult psyllids were liberated. A heavy population of nymphs soon developed. The early plants produced a fair crop for greenhouse conditions while the late plants, on account of the psyllids, produced few tubers of more than an inch diameter. At harvest all tubers were cut without necrosis being found.

FIELD PLOT DATA.—Results from field plot tests made during 1944 for psyllid and tuber flea beetle control throw some light upon insect relationship to necrosis. The variety used was Katahdin. Seven treatments were used and 5 applications made. Each treatment was replicated six times and each plot consisted of six rows 30 feet long. It will be seen from table 2 that the psyllid infestation was heavy and resulted in almost a complete crop failure on the checks. Necrosis was common in the tubers but the treatments had a highly significant effect upon the amount of necrosis as well as upon the psyllid population as shown by the sweeping records and the increased yield. It could be reasoned that the psyllid was directly associated with the necrosis. However, the great range in psyllid yellows that occurred under the various treatments made another condition more noticeable. The following field note was made October 2: "A number of plants in each plot show extreme purple top condition. It is somewhat different from the extreme purple top produced with psyllid yellows. The stems of the plants are of a dark purplish-green with aerial tubers often showing near the ground. Some plants indicate that fusarium may be associated. Tubers on many if not all of these plants show net necrosis. Net necrosis shows in tubers of some plants not showing this typical purple top. Plants with necrotic tubers cannot be readily detected in the check."

Table 2 gives the results of a count, made in the four center rows of each plot, of the plants showing this extreme purple top condition. It will be noted that the treatments had a strong effect upon the percentage of diseased plants. Sweepings were made during the season to determine the treatment effects upon the psyllid and tuber flea beetle populations. Records also were made of the leaf hoppers, but unfortunately they were not separated as to species. It is known, however, that the six-spotted leafhopper made up a considerable part of those taken. The data in table 2 indicate that the treatments

Table 2.—Effects of chemical treatments on certain insect populations, tuber yield and occurrences of tuber net necrosis.

Treatment	Yield of Tubers 1.87 in. Diameter or Larger		Pounds Necrotic Tubers per Plot	Diseased Plants per Plot	Insects per Plot Four Collections. 20 Strokes Each	
	Pounds per plot	Computed bushels per acre			Adult psyllids	Leaf-hoppers
Check. No treatment	0.51	1.03	0.93	7.66	46.67	93.0
Lime sulfur 2.5 gals., zinc arsenite 5 lbs., water 100 gals.	159.5	321.67	38.42	17.66	22.17	112.0
Dusting sulfur 60%, cryolite 40%	80.36	162.05	22.49	12.66	25.67	112.5
DDT 1 lb. (5 lbs. 20% concentrate) to 100 gallons water	211.21	425.94	12.97	3.33	6.67	33.0
DDT dust, 3% in inert carrier	156.50	315.62	17.41	6.33	18.00	59.3
1% DDT, 33.3 inert carrier, 66.67 sulfur	169.48	341.78	19.96	4.50	16.67	63.2
DDT—1 lb. dissolved in 1 qt. linseed oil, water 100 gallons	202.24	407.86	14.97	4.33	9.17	35.0
Diff. Req. for Sign.						
5% level	26.24[1]	8.82[1]	10.64[1]	8.47[1]	8.18	20.85
1% level	35.51[1]	11.94[1]	14.33[1]	11.45[1]	12.02	28.08

[1] Analysed without check.

definitely influenced the leafhopper population and that the leafhopper numbers correlate closely, except in the check, with the numbers of extreme purple top plants and the quantity of necrotic tubers.

There were strong indications from the 1944 field plot data that leafhoppers and not the potato psyllid were associated with net necrosis. With this as a guide an experiment was planned for 1945 using the technique previously described for studying aster yellows in asters and lettuce. The experiment consisted of four treatments, each replicated four times, in a latin square arrangement. Each plot was 6 feet square and contained 16 hills of Pawnee potatoes and 8 aster plants. Eight feet of space was left between plots. Low growing plants surrounded the experiment.

Treatment 1.—Fenced with 3-foot aster cloth to exclude leaf hoppers. Not treated for psyllids. Artificially infested with psyllids when it was noted the psyllid population was falling somewhat below that on the uncaged and untreated plots.

Treatment 2.—Dusted once each 7 days with dusting sulfur for psyllid control, beginning when the potato plants were 3 to 4 inches high. No leaf hopper control used.

Treatment 3.—Check. No treatments.

Treatment 4.—Dusted for psyllid control, and possibly some leafhopper control once each 7 days with a preparation containing 90 per cent dusting sulfur, 5 per cent DDT and 5 per cent inert carrier. The first application was made when the potato plants were from 3 to 4 inches high.

Table 3 gives some of the effects of the treatments on psyllid control, as expressed in nymphal populations and tuber yield and on the incidence of net necrosis in the tubers and aster yellows in aster blossoms. It will be noted that there were no significant differences in the number of tubers or the number of aster blossoms produced under the different treatments. This indicated that the psyllid yellows and aster yellows developed after the plants were well established. The psyllid counts on the five samples of potato leaflets and observation of the aster plants indicated this. The psyllid populations under treatments 1 and 3 were high and equal and the tuber yield was low and equal. However, there was a highly significant difference in the number of necrotic tubers. treatment 1 (caged) had a heavy psyllid population, but only 3 small potatoes that showed necrosis, while slightly more than 30 per cent of those from the uncaged plots of treatment 3, with an equal psyllid population were necrotic. The reverse was true with the diseased aster blossoms. The increase in disease under treatment 3, due supposedly to lack of protection from leaf hoppers, was highly significant.

The psyllid populations under treatments 2 and 4 were low and not significantly different. The increase in tuber yield over treatments 1 and 3 was very highly significant. Also the total tuber yield and the yield of tubers 1.87 inches or greater diameter from treatment 4 was

Table 3.—The effects of caging and chemical treatments on the incidence of net necrosis in potatoes and aster yellows in asters.

	Treatment Mean for						
Treatment	Total tubers	Necrotic tubers	Pounds tubers	Pounds tubers 1.87 in. or larger	Aster blossoms	Diseased aster blossoms	Psyllid nymphs 5–25 leaflet samples
Caged. No psyllid control—	132.0	0.75	9.65	4.18	194.5	25.0	151.2
Dusting sulfur—	154.2	20.00	29.88	22.30	135.2	93.0	9.0
Check. Uncaged. Untreated—	205.8	62.25	9.52	1.50	170.0	115.5	153.5
5% DDT in dusting sulfur—	184.2	28.75	36.18	26.68	127.5	64.0	4.0
Differences required for significance,							
5% level—		28.29	6.17	3.69		44.22	116.4
1% level—		42.85	9.34	5.60		66.99	
Significant effects shown by factorial analysis of variance							
psyllids—			**	**			
Leafhoppers—		*				**	
Interaction—		**					

significantly higher than for treatment 2. The DDT and sulfur dust gave a better control of the psyllids than did dusting sulfur alone. This agrees with results obtained from larger field plot tests. The difference in the number of necrotic tubers from treatments 2 and 4 was not significant, although the number of necrotic tubers was significantly lower than from the untreated check, indicating that the sulfur dust and the sulfur and DDT combination had some effect upon the cause of net necrosis. There was no significant difference in the number of diseased aster blossoms from treatment 2 and treatment 4, although there is a trend in favor of the sulfur-DDT combination. Apparently the chemical treatments afforded some protection against the carrier of aster yellows. The reduction in diseased blossoms due to the use of sulfur-DDT dust was significant when compared with the check. However, the chemical treatments did not give protection from aster yellows equal to that given by the fence cage.

When the effects of the treatments are broken down by a factorial analysis of variance, as shown in table 3, we find the psyllids had a highly significant effect upon the total yield of potatoes and the yield of tubers of 1.87 inches or greater diameter and no effect upon the occurrence of aster yellows in the aster blossoms or net necrosis of the tubers. On the other hand, the leafhoppers had a highly significant effect upon the number of diseased aster blossoms and a significant effect upon the number of necrotic tubers.

Observations during the 1946 season lend weight to the evidence that net necrosis in potatoes is a symptom of aster yellows and not of psyllid yellows. Aster yellows was very rare in asters, carrots, lettuce and other common hosts in the Fort Collins area. It was difficult to find diseased aster plants during the season for study purposes. Only an occasional wild lettuce plant showed it. In 1944 and 1945 a high percentage of the lettuce plants were infected. Net necrosis in potatoes also was rare during 1946. Not over a dozen typical plants that carried necrotic tubers were found in 3.5 acres of potato plots. Also there were no diseased asters or necrotic tubers in an experiment with 4 replications in which both asters and potatoes were grown without treatments. Psyllids were in sufficient numbers to reduce the yield of potatoes approximately 50 per cent.

SUMMARY.—Net necrosis of the potato is common in Colorado some seasons. It is most common in garden patches and small acreages. Necrotic tubers remain firm and have a brittle texture; the skin may have a dull, lifeless color, and in severe cases the eyes fail to grow. In less severe cases the sprouts are weak. Plants with necrotic tubers show many of the common symptoms that result from a failure to translocate elaborated plant food. The terminal growth is checked, internodes are shortened, and the edges of the leaflets curl upward at the base. The leaves and later the stem may show abnormal pigmentation, a pale yellow or purplish green color predominating. Axillary tubers may be formed. The symptoms are difficult to distinguish from those of the psyllid yellows induced by potato psyllid, *Paratrioza cockerelli* (Sulc). Net necrosis has been thought to be associated with psyllid yellows. However, no evidence was obtained from greenhouse and field tests to indicate that psyllids cause tuber necrosis. Since potatoes do not grow normally when caged, evidence of the effectiveness of aster cloth fences in protecting small plots of asters against the six-spotted leafhopper *Macrosteles divisus* (Uhl.) is presented to justify the use of such means to protect potatoes against this insect.

A careful analysis of data from caged and uncaged plots shows that protection from attack of the six spotted leafhopper prevents aster yellows in asters and net necrosis in potatoes. A heavy psyllid infestation within such a cage used to protect against the leafhopper produced no necrosis. Strong evidence is presented to the effect that net necrosis of the potato in Colorado is brought about as an effect of aster yellows.—12-2-46.

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Effect of Dusting Schedules on the Yield of Cotton[1]

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In recent years entomologists and plant physiologists have been concerned with factors affecting the fruiting and shedding of cotton. These studies have shown that the numbers of early set fruit are not indicative of the final yield. Eaton (1931) produced an increase in the number of bolls when all the flowers were removed during the first 25 days of the flowering period. Hamner's (1941) observations indicate that no reductions in yield occurred when all small squares were removed through a six-week period. Dunnam *et al.* (1943) did get a loss in yield where all week-old squares were removed for a 9-week period, but the yield wasn't significantly reduced by removal of all squares during the first 4 weeks of the fruiting period. This work indicates that all fruit can be removed through the first week in July in the central part of the cotton belt and the cotton may make a normal yield. These facts have a direct relation to the time of applying insecticides for the most economical returns.

The present recommendations are for dusting, beginning with a 10 per cent weevil infestation in most states, and the planters are urged by some entomologists to apply calcium arsenate to kill the overwintering weevils if large numbers are present when cotton is in the pre-square stage. These practices help to set the early bolls, but have not proven to be the most economical in all areas. Early dusting with calcium arsenate kills most of the parasites and predators of both aphids and bollworms, thus contributing to the damage caused by both insects. In some years aphids cause a loss in yield when partial defoliation occurs before the bolls are mature. Bollworms may cause more injury where early applications of calcium arsenate have been made. However, increased poundage of this insecticide will control the worms, but where the poundage is kept low as used for weevil control the bollworm damage is often severe. In this State the frequent occurrence of the bollworm during July makes it necessary to protect the fruit during this period requiring a long dusting program, if applications are made for early weevil control.

The cotton flea hopper has caused severe damage to the early fruit, but during 1926, when this pest was reported to be most injurious, the yields were high. During that year the fruit was produced late after the flea hopper ceased to be injurious. Records over a period of years taken in this vicinity indicate that the hopper very seldom prevents all the squares from setting and the injury is usually over by early July. Apparently cotton protected during the last three weeks in July and August will yield as much as the soil is capable of producing considering the weather conditions.

Experiments were conducted in the Brazos River bottom near College Station and in creek bottoms near Terrell during 1946 to compare early and late dusting schedules. The experiments were conducted in a similar manner at both locations using acre-sized plats. The three schedules compared in these tests were: (1) early dusting to control thrips, followed by complete weevil and bollworm control, (2) dusting for standard weevil and bollworm control and (3) late dusting for weevil and bollworm control. The infestation records were made at three points in each plat in the usual manner throughout the season. Summaries of these records are shown in Tables 1 and 2.

Results at College Station: The thrips population was low early in the season causing little, if any, injury. However, the percentages of so-called "thrips injured" plants were 44 on plat A and 43 on plat B. Apparently there were other factors which caused bud injury and malformed plants. The two applications of 5 per cent DDT-sulphur mixture applied at the rate of 15 pounds per acre did not affect the percentage of malformed plants. These early applications and a pre-square calcium arsenate application did not increase the yield. It will be noticed that the average weevil infestation was about 50 per cent during the period June 14 to July 11 preceding the first dust application on the late treated plat. The six applications ap-

[1] Technical contribution No. 986 Texas Agricultural Experiment Station in cooperation with the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture.

Table 1.—Thrips population, punctured squares, injured bolls, dates dust applications were made and yield on plats at College Station, Texas.

	A—Check[1]		B—Calcium Arsenate[1]			C—Calcium Arsenate[1]			D—Sulphur 20% Calcium Arsenate[1] 70% 50% DDT 10%		
Date	Sqs. Pct.	Bolls Inj.	Dusted	Sqs. Pct.	Bolls Inj.	Dusted	Sqs. Pct.	Bolls Inj.	Dusted	Sqs. Pct.	Bolls Inj.
	Per Cent	*Per Cent*	*Date*	*Per Cent*	*Per Cent*	*Date*	*Per Cent*	*Per Cent*	*Date*	*Per Cent*	*Per Cent*
5/24	300[4]		5/11[3]	555[4]			555[4]			755[4]	
5/29	705[4]		5/25	300[4]		5/25	450[4]			645[4]	
6/14	80.3			78.0			75.3			51.7	
6/19	76.7		6/15	28.0		6/15	23.3			59.0	
6/24	31.3		6/20[3]	12.7		6/20	15.3			57.7	
6/28	34.0		6/24	8.0		6/24	10.3			30.7	
7/3	30.7		6/29	25.7		6/29	10.0			18.7	
7/8	77.3		7/5	14.7		7/5	24.0			71.7	
7/11	71.3		7/12	9.3		7/12	5.3		7/12	76.0	
7/16	60.0		7/17	19.0		7/17	9.7		7/17	31.3	
7/22	36.3	20.3	7/23	3.0	3.3	7/23	8.7	2.7	7/23	12.0	4.0
7/27	78.0	6.3	7/29	8.3	2.3	7/29	35.7	11.0	7/29	33.7	10.3
8/1	62.0	24.3	8/5	—	11.0	8/5	—	18.3	8/5	47.3	4.0
8/6	59.3	14.7		—	11.0		—	12.3	8/12	17.0	7.3
Ave.	56.1	16.4		14.3	6.9		15.8	11.0		28.3	6.4

[1] Seed cotton per acre: A—823 lbs.; B—1301 lbs.; C—1358 lbs.; D—1297 lbs.
Thrips per plant 5/2: A—0.3; B—0.3; C—0.3; D—0.2. 5/18: A—0.1; B—0.1.
[2] 5% DDT-Sulphur mixture was used.
[3] Washed off by rain.
[4] Weevils per acre.

Table 2.—Thrips populations, punctured squares, dates dust applications were made and yield on plats at Terrell, Texas.

	A—Check[1]		B—Calcium Arsenate[1]			C—Calcium Arsenate[1]			D—Calcium Arsenate[1]		
Date	Thrips Per Plant	Squares Punctured	Thrips Per Plant	Aquares Punctured	Dusted	Thrips Per Plant	Squares Punctured	Dusted	Thrips Per Plant	Squares Punctured	Dusted
	Number	*Per Cent*	*Number*	*Per Cent*	*Date*	*Number*	*Per Cent*	*Date*	*Number*	*Per Cent*	*Date*
5/6	.2		.2		5/7[2]	.3			.4		
5/18	2.2		.6			1.9			3.0		
5/28	10.6		9.9			12.8			22.0		
6/3	18.2		12.5		6/5[2]	22.3			37.9		
6/11	25.0		16.2			14.4			22.2		
6/15		88.0		87.0			85.0			92.0	
6/19	7.4		5.1			9.4			6.4		
6/21		55.8		59.6	6/22		65.4	6/22		60.8	
6/26		47.5		41.8	6/27		41.2	6/27		62.2	
7/1		42.8		9.3	7/2		12.5	7/2		47.5	
7/6		57.3		10.7			13.8			56.2	
7/11		83.0		41.8	7/12		31.8	7/12		75.7	
7/16		87.7		38.7	7/17		31.3	7/17		87.7	7/17
7/22		64.2		7.8			13.0			30.6	7/23
7/27		45.3		18.7			14.0			18.0	
8/1		46.5		26.0	8/2		23.0	8/2		31.0	8/2
Ave.	12.7	59.3	8.7	24.4		12.2	22.6		18.3	26.5	

[1] Seed cotton per acre: A—610 lbs.; B—716 lbs.; C—740 lbs.; D—662 lbs.
[2] 5% DDT-Sulphur mixture was used.

plied to this late treated plat reduced the weevil infestation to an average of 28 per cent, gave adequate bollworm control and resulted in practically as high a yield of cotton as either of the other two plats where eleven and thirteen dust applications were made. The calcium arsenate-DDT-sulphur mixture did not give any better control of the bollworm than calcium arsenate alone. The insecticides were applied at the rate of 5 to 7 pounds per acre before July 12, but were increased on all plats to 12 to 14 during the remainder of the season.

Results at Terrell: The thrips population was high early in the season, but caused comparatively low percentages of malformed plants as follows: plat A, 16 and plat B, 13. The two applications of 5 per cent DDT-sulphur mixture tended to reduce the thrips population and malformed plants. However, this reduction did not prove to be profitable as indicated by the yields on these two plats. It will be noticed that the average weevil infestation was about 69 per cent during the period June 15 to July 16 preceding the first dust application on the late treated plat. All schedules failed to produce profitable increases in yields in spite of the fact that a large increase in forms was observed in the treated plats early in July. During the latter part of July a high percentage of the forms that had been set as a result of weevil protection shed and the final yield was reduced to that which the soil could support. Apparently enough fruit was set without any protection from insect injury so that the yield was as much as the soil was capable of producing under the existing weather conditions.

SUMMARY.—Protection of the squares early in the season helped to set the early early bolls but failed to produce an increase in the total yield. At College in the delayed schedule picking was about two weeks later than in the early dusting schedule, but all cotton was harvested by September 18. Apparently the loss of about 50 per cent of the squares during the first 30-day period of fruiting did not affect the yield at College Station where adequate protection was given the fruit from the ravages of both the weevil and bollworm later in the season. At Terrell a large percentage of the additional fruit set by protecting the squares from weevils shed, thus reducing the final yields on these plats to a small increase over the check. Apparently the seasonal average loss of about 60 per cent of the squares did not greatly reduce the yield of cotton planted on this soil. Forty per cent of uninjured squares produced by the plant were sufficient to yield about all the soil was capable of producing. These results indicate that it may be more profitable to dust cotton during the last three weeks of July and August at which time the weevils and bollworms are most injurious in these areas than to try to protect the fruit during the entire season.—11-9-46.

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WANTED

ENTOMOLOGISTS: Assistant Entomologist with possibility of Associate Entomologist for better qualified applicant, Agric. Experiment Station, salary dependent on qualifications. Assistant Professor or Associate Professor, grade and salary dependent on qualifications. University of Hawaii. Ph.D. preferred. Write (air mail):

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Effect of Humidity on the Toxicity of Certain Organic Compounds to Eggs of the Body Louse[1]

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Commercial samples of MYL, a louse powder developed by Bushland *et al.* (1944), were tested at the Orlando, Fla., laboratory in January 1943 and found to be ineffective against eggs of the body louse, *Pediculus humanus corporis* Deg. Previous lots had caused complete kill of eggs in laboratory tests and on research subjects artificially infested with eggs. Since the relative humidity in the temperature cabinet in which the treated eggs were held was known to be low, probably around 40 per cent, experiments were designed to determine the effect of atmospheric moisture upon the ovicidal value of the MYL louse powder and upon 2,4-dinitroanisole, the ovicide in the powder. In another experiment, tests were made with various organic compounds which the author had previously found to be ovicidal at high humidities.

The findings of these tests were communicated to workers of the Rockefeller Foundation, and certain of the ovicides were retested by entomologists of that organization. Hansens (1944) confirmed the observation reported herein that the ovicidal effects of dinitroanisole, benzocaine, and certain other compounds are dependent upon a high humidity. Lindgren & Shepard (1932) showed that certain fumigants were more effective at high than at low humidities against the eggs of *Tribolium confusum* Duv.

MATERIALS AND METHODS.—Louse eggs up to 2 days old and from 4 to 6 days old were used in each test. In the first experiment the desired humidities were obtained with saturated salt solutions and in the second with sulfuric acid-water mixtures. The final humidities were determined with a hair hygrometer.

Most of the tests were made with the ovicide mixed with pyrophyllite. The test material was deposited on the pyrophyllite from an acetone solution, allowed to dry, and then ground to a fine powder on a glass plate. A cloth pad a half-inch square bearing 100 to 150 eggs was thoroughly dusted with the powder and the excess was removed by shaking. The pads were suspended on pins and placed inside sealed *Carr*-type desiccators. The desiccators were then placed inside a temperature cabinet held at 30° ± 2° C.

TESTS WITH DINITROANISOLE AND MYL FORMULA.—In the first experiment 2,4-dinitroanisole, 2 per cent and 5 per cent, was tested alone and in combination with 2 per cent of N-isobutyl-undecylenamide.[2] The MYL formula[3] contains these two ingredients at the 2 per cent concentrations. For comparison, three commercial batches of MYL, one of which had previously given incomplete kill of eggs, were included in these tests. The treated eggs were placed inside desiccators at relative humidites of 26, 66, 81, and 100 per cent.

Since no hatching occurred among the treated eggs held at humidities of 66, 81, or 100 per cent, only the results obtained with the eggs held at 26 per cent are included in table 1. Good hatch of the untreated eggs, which were used as a check, was obtained at all humidities except 100 per cent; however, at this humidity the untreated eggs 4 to 6 days old were not greatly affected. The percentage hatch of the treated eggs up to 2 days old was similar to that of the untreated eggs.

Louse eggs held in closed vessels over water are sometimes affected by mold growths, as was the case in these tests. The importance of these growths as a contributing factor in the mortality of the eggs is not known. However, in tests conducted under aseptic conditions little kill of eggs was noted when normal eggs were dipped in alcohol. Contrary to published data (Chandler 1944), extremely low humidities did not appear to affect the normal development and hatch of eggs.

These results indicate that the ovicidal

[1] This work was conducted under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development to the Bureau of Entomology and Plant Quarantine.

[2] *IN-930.*

[3] Pyrethrins (from a 20 per cent concentrate) 0.2 per cent, N-isobutyl-undecylenamide 2.0 per cent, 2,4-dinitroanisole 2.0 per cent, *Phenol S* (chiefly isopropyl cresols, by-product of thymol manufacture) 0.25 per cent, pyrophyllite to make 100 per cent.

Table 1.—Toxicity of dinitroanisole and MYL formula to eggs of the body louse at a relative humidity of 26 per cent.

Treatment	Per Cent Hatch of Eggs	
	0 to 2 Days Old	4 to 6 Days Old
Dinitroanisole (in Pyrophyllite)		
2%	87	97
2% plus N-isobutyl-undecylenamide 2%	86	94
5%	88	95
5% plus N-isobutyl-undecylenamide 2%	70	92
MYL:		
Sample 1	83	94
2	80	93
3	86	90
Check (untreated)[1]	92	96

[1] Average of 2 samples.

value of dinitroanisole is greatly affected by atmospheric moisture, whether tested alone or in combination with N-isobutyl-undecylenamide or pyrethrum.

COMPOUNDS OF DIFFERENT SOLUBILITY IN WATER.—In the second experiment tests were made with several unrelated compounds of different solubility in water. These materials were selected to determine whether the effect of humidity was limited to certain compounds or classes of compounds, and also whether there was any correlation between their solubility in water and the effect of humidity upon their toxicity to louse eggs. All the ovicides were tested at 10 per cent in pyrophyllite, which was at least twice the concentration known to give complete kill of eggs under high humidity. The louse eggs were dusted and placed inside desiccators at relative humidities of 27, 45, 63, and 80 per cent. Since in the previous tests dinitroanisole gave complete kill of eggs at 100, 81, and 66 per cent humidity, but not at 26 per cent, the intermediate humidity of 45 per cent was included in an attempt to further establish the critical range.

At a relative humidity of 80 per cent all the ovicides gave complete kill of eggs. The results obtained at the other humidities are shown in table 2. At 63 per cent the kill of eggs 4 to 6 days old was incomplete, and also of eggs up to 2 days old except those tested with azoxybenzene, 2,4-dinitrophenol, and formanilide. At 45 per cent humidity 2,4-dinitrophenol and thymol were the only compounds that showed any toxicity to the older eggs, and azoxybenzene and formanilide were the only materials that gave complete kill of the younger eggs. At 27 per cent formanilide was the only material to kill all the younger eggs, but it was entirely ineffective against the older eggs. Dinitrophenol

Table 2.—Toxicity to louse eggs of certain organic compounds of different solubility in water at various relative humidities.

Treatment (10% in Pyrophyllite)	Solubility[1] (Grams per 100 ml. of Water)	Per Cent Hatch of Eggs Held at Relative Humidities of—					
		27 Per Cent		45 Per Cent		63 Per Cent	
		up to 2 Days Old	4 to 6 Days Old	0 to 2 Days Old	4 to 6 Days Old	0 to 2 Days Old	4 to 6 Days Old
m-Nitroacetophenone	Insoluble	96	98	81	94	10	17
Azoxybenzene	Insoluble	14	96	0	94	0	94
2,4-Dinitroanisole	Slightly soluble, hot	94	96	94	98	72	92
Diphenylamine	0.03^{25}	42	98	10	96	4	84
2,4-Dinitrophenol	$.56^{18}$ 4.3^{100}	19	47	8	50	0	4
Thymol	$.085^{20}$ $.132^{37}$	57	98	6	33	12	40
Formanilide	Soluble	0	96	0	94	0	8
Piperonal	.2 cold ∞^{78}	86	100	40	98	4	84
Ethyl *p*-aminobenzoate	.04	90	94	90	96	33	98
Check (untreated)[2]	—	98	97	98	96	98	94

[1] Taken from Handbook of Chemistry and Physics (Chemical Rubber Publishing Co., 1943–44). Normal room temperature (20° C.) is assumed unless the temperature is indicated by a superior figure. The term "insoluble" must usually be interpreted to mean that a negligible quantity of the compound dissolves. The term "soluble" is used for lack of a definite figure.

[2] Average of 2 samples.

was the only material to affect eggs 4 to 6 days old held at this humidity.

The difference in the results obtained with the above compounds was probably due partly to individual variations in ultimate toxicity and partly to different rates of toxic action. The ovicide must kill 4- to 6-day old eggs within 24 to 48 hours or hatching will occur. Any piece of cloth containing eggs in this age range may actually contain more 6-day-old than 4-day-old eggs, and this may cause some variation in results. With the eggs up to 2 days old both the ovicide and the humidity have more time to show their effects.

When the results obtained with *m*-nitroacetophenone, an insoluble compound, are compared with those obtained with piperonal, a material fairly soluble in water, there appears to be no correlation between their solubility in water and the extent to which their toxicity is affected by humidity.

POWDERS CONTAINING A HYGROSCOPIC AGENT.—In the third experiment tests were made with pyrophyllite powders containing either 5 per cent of dinitroanisole, alone or in combination with 1 per cent of glycerol, or 5 per cent of ethyl *p*-aminobenzoate, alone or in combination with 1 per cent of dipropylene glycol. The relative humidities used were similar to those given in table 2. It was thought that the addition of a hygroscopic material might alter the effect of changes in atmospheric humidity upon the toxicity of the ovicide. However, the results with dinitroanisole and *p*-aminobenzoate alone were similar to those obtained with the combinations.

SOLUTIONS.—Ovicides have been found much more effective when applied as solutions (in alcohol, ether, acetone, or chloroform) than as powders in pyrophyllite.

A fourth experiment was made to determine the effect of humidity on the toxicity of the materials applied as solutions. The cloth pads bearing the eggs were dipped in ethyl alcohol solutions of the ovicides and immediately placed in desiccators held at various relative humidities. The 5 per cent concentrations of all the materials at any humidity caused complete kill. However, when lower concentrations were employed, the kill varied with the humidity in the same manner as in the tests with powders, although the effect of the humidity was not so marked.

SUMMARY.—The toxicity of MYL louse powder, *m*-nitroacetophenone, azoxybenzene, 2,4-dinitroanisole, diphenylamine, 2,4-dinitrophenol, thymol, formanilide, piperonal, and ethyl *p*-aminobenzoate against the eggs of the body louse, *Pediculus humanus corporis* Deg., was shown to be greatly affected by atmospheric moisture. In general the materials gave excellent kill of eggs, the results depending somewhat upon the age of the eggs tested, at relative humidities of 80 per cent or higher, but little or no kill at 63 per cent or lower. The results with some compounds were definitely more affected by atmospheric moisture than was the case with others. No correlation was noted between the solubility of the compound in water and the effect of relative humidity upon its toxicity to eggs.

Extremely low humidities did not prevent the hatching of normal eggs. Some mortality of eggs occurred when they were held in closed desiccators over water and became affected by mold growths. However, little kill was noted when the eggs were dipped in alcohol and handled under aseptic conditions.

The addition of two hygrosopic materials, glycerol and dipropylene glycol, to 2,4-dinitroanisole and ethyl *p*-aminobenzoate, respectively, did not affect the kills caused by these compounds over a range of humidities.

Ovicides were more effective when applied as an alcoholic solution. However, when treatments were made at low concentrations, mortalities varied with humidity in the same manner as with powder treatments.—12-14-46.

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Residual Spray Applications to Salt-Marsh and Jungle Vegetation for Control of Mosquitoes[1]

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Field tests conducted during the summer of 1944 demonstrated the practicability of DDT residual treatments applied to jungle vegetation for the control of adult mosquitoes (Madden *et al.* 1945). The results indicated that this method of control might be of importance against disease-carrying and pest mosquitoes. Additional work was conducted during the active mosquito season of 1945. DDT in various forms was tested and the investigations were extended to include a few other insecticides. The residual treatments were applied to salt-marsh vegetation and to vegetation and surface litter in the jungle. Tests were directed mainly against the salt-marsh species *Aëdes taeniorhynchus* (Wied.) and *A. sollicitans* (Walk.).

Salt-Marsh Tests.—The purpose of these investigations was to determine the possibility of applying DDT residual treatments to salt-marsh vegetation in or near the sources of breeding as a means of control against salt-marsh mosquitoes. Both newly emerged adults and gravid females of these species rest for a time on salt-marsh vegetation, and it appeared probable that as a result they would be killed when exposed to DDT.

The tests were conducted in an extensive salt-marsh area lying along the east side of Mosquito Lagoon several miles south of New Smyrna Beach, Fla. An undrained section of marsh was chosen so that flooding would permit larval development and subsequent emergence of adults. Square plots varying in size from 0.625 to 3 acres were established in the area selected. All plots were in the open marsh with no trees or other canopy to provide protection from direct sunlight.

The treatments were applied with 3-gallon, hand-operated pressure sprayers. Nozzle discs with 0.055-inch diameter orifices produced a moderately coarse residual-type spray. Materials were sprayed in 6-foot swaths on the marsh grasses and pickleweed (saltwort) covering the plots. The pressure produced by the equipment (25 to 40 pounds per square inch) was too low to drive the spray through the dense grasses to the soil surface where it might act as a residual larvicide treatment. A solution consisting of 5 per cent of DDT in No. 2 fuel oil, a 5 per cent aqueous emulsion,[2] and two 5 per cent DDT suspensions were used. Rates of application were from 5 to 30 gallons per acre.

Normal flooding of the marsh did not occur owing to the absence of high spring tides and an unusually long dry season. Thus hatching of eggs was retarded and no breeding took place until late in the summer. The rainy season began about the first of July and precipitation was rather heavy. Records obtained at the official Weather Bureau station about 4 miles north of New Smyrna Beach showed that the rainfall was slightly below normal in July (5.9 inches) and substantially above normal in August (7.1 inches).

Under the above circumstances the proposed method of evaluating the results of the treatments by direct observations and trapping records was delayed until the latter part of the season. In the interim the following method was substituted. At intervals after the treatment of each series of plots a sample of vegetation was collected from five well-distributed points in each plot. Houseflies, *Musca domestica* L., and mosquitoes, *Anopheles quadrimaculatus* Say, were exposed to these samples in glass jars for 24 hours and the mortality was recorded. The insects were supplied with food and water during the exposure period.

The initial treatments were applied at the rate of 5 gallons per acre and 10 gallons per acre. The suspension used consisted of equal parts of DDT and talc plus a wetting agent. Records of the toxicity tests conducted with samples from these plots are presented in table 1. The best results against both mosquitoes and

[1] This work was conducted under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development to the Bureau of Entomology and Plant Quarantine.

[2] Made from a concentrate containing 25 per cent of DDT, 7 per cent of *Triton X-100* (polyethyloneglycol alkyl aryl ether) and 68 per cent of xylene.

Table 1.—Mortality of houseflies and mosquitoes exposed to samples of vegetation treated with a 5 per cent solution, emulsion, and suspension at dosages of 5 or 10 gallons per acre.

Material	Gallons per Acre	24-Hour Mortality in Per Cent after— 19 Days		29 Days		36 Days		51 Days	
		Mosquitoes	Houseflies	Mosquitoes	Houseflies	Mosquitoes	Houseflies	Mosquitoes	Houseflies
DDT (5 per cent):									
Soulution	10	84	99	74	41	75	5	65	65
	5	72	89	58	20	26	0	44	0
Emulsion	5	48	98	16	32	80	58	13	2
Suspension	5	34	77	4	26	10	7	3	0
Check (untreated)		0	7	3	0	8	4	0	0

houseflies were obtained with the samples treated with the solution at the higher dosage. Results against houseflies with samples collected 29 and 36 days after treatment were very poor, but a fairly high mortality (65 per cent) of both house flies and mosquitoes was obtained 51 days after treatment. The emulsion and the solution applied at the same dosage appear to have been about equally effective, but much higher mortality was obtained with the emulsion treatment 36 days after application. The suspension was the least effective of the treatments, particularly against mosquitoes, and even 19 days after application only a moderate kill was obtained. No sticker was used with this suspension.

In a second series of plots the treatments were applied at the rate of 20 gallons per acre and 10 gallons per acre. A suspension containing 90 per cent of DDT[1] was used. Records of toxicity tests conducted with samples taken from these plots are given in table 2. Some rather erratic results were obtained, but in general the emulsion and suspension treatments were the most effective against both insects up to 29 days after application. The effectiveness of the solution at higher dosage fluctuated, but the general trend was toward a higher percentage mortality than that obtained with the lower dosage up to 29 days after application. Sixty days after application the lower dosage gave the highest kill. Most likely the heavy dosage had killed much of the original vegetation. As a result the succulent growth shriveled to a fraction of its former surface area, and at the time these samples were collected a considerable amount of fresh untreated vegetation was present in the plot. This burning of the vegetation may account also for the decrease in effectiveness of the emulsion treatment, but it does not explain a similar condition with regard to the suspension, since no burning occurred with any of the suspension treatments.

A third series of plots was treated at dosages of 15 and 30 gallons per acre with the solution, and 30 gallons per acre with

[1] Prepared by Dr. G. D. Patterson of the National Defense Research Committee.

Table 2.—Mortality of houseflies and mosquitoes exposed to samples of vegetation treated with a 5 per cent DDT solution, emulsion, and suspension at dosages of 10 or 20 gallons per acre.

Material	Gallons per Acre	24-Hour Mortality in Per Cent after— 7 Days		14 Days		29 Days		60 Days	
		Mosquitoes	Houseflies	Mosquitoes	Houseflies	Mosquitoes	Houseflies	Mosquitoes	Houseflies
DDT (5 per cent):									
Solution	10	61	13	100	46	84	21	80	81
	20	97	100	47	12	98	45	50	16
Emulsion	20	99	100	100	90	100	100	25	25
Suspension	20	79	100	100	100	78	83	30	16
Check (untreated)		3	0	8	4	0	0	3	0

Table 3.—**Mortality of mosquitoes and houseflies exposed to samples of vegetation treated with a 5 per cent DDT solution, emulsion, and suspension at dosages of 15 and 30 gallons per acre.**

Material	Gallons per Acre	24-Hour Mortality in Per Cent after—					
		1 Day		15 Days		46 Days	
		Mosquitoes	Houseflies	Mosquitoes	Houseflies	Mosquitoes	Houseflies
DDT (5 per cent):							
Solution	15	100	100	96	100	96	18
	30	97	98	100	100	26	40
Emulsion	30	100	100	88	100	66	45
Suspension	30	100	100	100	100	82	14
Check (untreated)		8	4	0	0	3	0

the emulsion and the suspension used in the second test. Complete or nearly complete kill of both insects was obtained by 15 days after application (Table 3) with all treatments except the emulsion, which caused only 88 per cent mortality of mosquitoes. The solution applied at the rate of 15 gallons per acre and the suspension gave a high kill of mosquites 46 days after treatment, but all other kills were low. Apparently burning of the vegetation was again responsible for the poor results obtained with the high dosages.

Adult emergence and abundance was too small to permit making direct observations and tests until the latter part of July and in August. Even then breeding was limited mainly to the holes of crabs, since standing water was present only for very short periods following heavy rains.

All plots were subject to reinfestation every night. However, adult landing-rate counts taken in the larger treated plots (0.25 to 3 acres) shortly before the usual night activity were generally about 40 per cent lower than in the untreated marsh. In a 3-acre plot treated with a 5 per cent DDT solution at the rate of 10 gallons per acre, the normal insect population other than mosquitoes—grasshoppers, leafhoppers, small moths, etc.—was estimated as being about 90 per cent less than in the surrounding untreated area 3 weeks after treatment.

Trapping records were obtained by placing cages 6 feet square and 2 feet high, covered with 16-mesh screen, over the marsh growth to capture adults attempting to leave at night. A small trap consisting of a half-pint mason jar inverted over a screen cone was fitted into each corner of the top of a cage. The mosquito counts made in a plot treated with a 5 per cent DDT solution at the rate of 10 gallons per acre and in an untreated plot are compared in table 4. The cages were moved about from place to place in the plots, and were operated intermittently for 14 nights or until 21 days after the treatment was applied. During this period the average number of mosquitoes captured in the treated plot was 52 per cent less than in the untreated plot. Part of this reduction may have been due to the larvicidal action of the treatment, since less breeding was occurring in the treated plot than in the check. Possibly newly emerged adults did not comprise the entire catch, as others may have sought shelter under the cages. However, it appears that such a factor would have been about equal in both the treated and untreated areas.

JUNGLE TESTS.—The purpose of these investigations was to determine the relative effectiveness of several residual-type spray treatments against adult mos-

Table 4.—**Counts of adult salt-marsh mosquitoes caught in a plot treated with a 5 per cent DDT solution and in an untreated plot.**

Nights Trap Was Operated	Mosquitoes Caught		Reduction in Treated Plot
	Untreated Plot	Treated Plot	
	Number	*Number*	*Per Cent*
1	61	43	30
1	25	12	52
5	154	41	74
1	33	30	9
2	37	18	51
1	21	7[1]	33
1	16	10[1]	62
2	40[1]	25	38
Totals 14	387	186	—

[1] Average of 2 traps.

quitoes under jungle conditions. Laboratory experiments had shown that the addition of piperonyl cyclohexenone to pyrethrum greatly enhanced the residual properties of the pyrethrum. To obtain information on the effectiveness of such a combination in the field, a spray solution containing 1 per cent of pyrethrins and 5 per cent of piperonyl cyclohexenone in kerosene was tested. For similar reasons a test was made of a 5 per cent benzene hexachloride aqueous emulsion,[1] and a suspension containing 5 per cent of DDT[2] was included in the series. These preparations were compared with 5 per cent of DDT in No. 2 fuel oil which was used almost exclusively in the 1944 tests (Madden *et al.* 1945). The dosage in each case was 5 gallons of material per acre. The treatments were applied in 15-foot swaths to the surface litter and vegetation up to a height of about 5 feet with the sprayers used in the marsh tests. Little mechanical difficulty was experienced in spraying, except for some clogging of the nozzle with the DDT suspension. More thorough application may have been obtained with this material, however, because the deposit was clearly visible as a series of white spots on the leaves, thus making it possible to insure complete coverage.

The test area consisted of two small strips of jungle about a half-mile apart, and the cover was a mixture of hardwoods and cabbage palms with a scattered understory of vines and young growth. Four square plots 1 acre in size were located in each strip. Each series of plots was arranged in a row, and the four treatments were replicated at random in both cases. One row of plots was on low ground which was partially under water at times, whereas the other row was on higher ground which remained comparatively dry for the greater part of the season.

The mosquito population consisted mainly of the salt-marsh species with occasional numbers of fresh-water breeders, *Psorophora* spp. Owing to the late occurrence of the rainy season and the lack of sufficient mosquitoes, the tests could not be conducted in the area until after the first of July. Counts were terminated after August, because observations showed that the population had been so reduced that no conclusive records could be obtained after that time.

Rainfall was somewhat above normal in the area during the early part of the observation period. Records obtained at the official Weather Bureau Station near Titusville, about 5 miles from the test area, showed 9.85 inches for July but only 4.96 inches for August. Once a heavy shower fell about 45 minutes after the application of the DDT suspension, but no other rain fell on fresh treatments.

The treatments were evaluated by weekly determinations of the density of the mosquito population within the plots and in adjacent untreated check areas. This was accomplished by counting the number of mosquitoes landing on the clothing of the observer in 1-minute intervals. A number of such counts were made within and outside the plots at each observation period. As was the case with the marsh plots, nightly reinfestation probably occurred. Therefore, counts were always made in the afternoon so that the treatments would have time to affect fresh individuals resting in the plots.

The results of these tests are presented in table 5. The records represent the average of both replications in each case. Reductions obtained with the pyrethrum treatment were not particularly high even during the first week after application, and practically all of its effectiveness had disappeared in 26 days. Similar results were obtained with the benzene hexachloride emulsion. However, because the

Table 5.—Control of adult mosquitoes in jungle plots treated with pyrethrum, benzene hexachloride, and DDT applied as residual sprays.

Time after treatment (Days)	Per Cent Reduction with—			
	Pyrethrum Solution	Benzene Hexachloride Emulsion	DDT Solution	DDT Suspension
5	60	70	86	88
12	50	70	88	85
19	48	68	86	78
26	47	64	70	78
33	0	22	68	75
39	28	28	57	70
46	24	25	52	76
53	20	26	41	64

[1] Made from a concentrate containing 15 per cent of crude benzene hexachloride (12 per cent of gamma isomer) and 15 per cent of *Triton X-100* in benzene prepared on a weight-per-weight basis.

[2] Made by adding the proper amount of water to a concentrate containing 90 per cent of DDT, which was also prepared by Dr. G. D. Patterson.

crude product used contained only about 12 per cent of the active insecticidal ingredient, the dosage per acre was actually less than that of the pyrethrum. A fair reduction was obtained with the DDT solution through the third week, but after that time there was a decrease in effectiveness. The DDT suspension was the most persistent, and gave good results until the end of the observations.

For a comparison of the relative toxicity of the treatments, samples of vegetation and debris were collected in each of the plots 33 days after spraying. These samples were tested against houseflies by the same method as was used with the marsh samples. The mortalities obtained after 3 and 15 hours of continuous exposure were 0 and 5 per cent for the pyrethrum solution, 0 and 8 per cent for the benzene hexachloride emulsion, 79 and 99 per cent for the DDT solution, and 98 and 100 per cent for the DDT suspension. These results are in close agreement with the records obtained by the landing-rate counts, and therefore serve to confirm the results of the field work.

CONCLUSIONS.—The results of the residue tests in the marshes provide rather satisfactory evidence of the promising possibilities of such treatments as a means of controlling mosquitoes which breed in these or similar areas. This is of considerable practical importance since it provides a means of control before the adults become disseminated, even when the vegetation is too dense to permit successful larviciding operations. Both high and low dosages of solutions and emulsions appear to have a limited duration of effectiveness. This is because of burning of the foliage in the case of the higher dosages with oil solutions. Thus medium dosages appear to be the most satisfactory both from the standpoint of maximum persistence and cost of labor and materials. Further work is needed on a rather large scale to determine the effectiveness and cost of this method. Effectiveness was not so great or so prolonged as was the case with treatments applied to jungle vegetation. Exposure to sunlight probably is one of the reasons for this, since Lindquist *et al.* (1945) have shown that sunlight causes some decomposition of DDT. However, the main reason probably is that the physical characteristics and density of the saltmarsh vegetation make it difficult to obtain as thorough application of material as is possible in the jungle.

The jungle tests show that the DDT suspension was the most effective of the treatments tried but there are reasons to believe that benzene hexachloride applied at the same dosage might be equally effective or more so. Under present conditions, however, such a dosage of this material would be impractical.

SUMMARY.—Residual type spray treatments were tested against adult saltmarsh mosquitoes both on the open marsh and in the jungle. Marsh tests were undertaken to determine the possibilities of this method of control against newly emerged adults or gravid females. DDT solutions, emulsions, and suspensions were tested at dosages varying from 5 to 30 gallons per acre. Results were determined by exposing houseflies and mosquitoes to samples of vegetation collected in the plots and by direct observations on adult reduction and trapping records. The indications were that such treatments represent a promising method of control. The jungle tests were made to compare the relative effectiveness of pyrethrum activated with piperonyl cyclohexenone, a benzene hexachloride emulsion, and a DDT suspension with that of a DDT solution used in previous investigations. Results were determined mainly by checking landing-rate counts of mosquitoes. The DDT suspension was the most effective, but at an equal dosage it appears that benzene hexachloride might be equal to or better than this preparation. Treatments were not so effective on the marsh as in the jungle. This is attributed in part to the effects of sunlight, but the main reason appears to be that the density and physical properties of the marsh vegetation do not permit so thorough a treatment as is possible under jungle conditions.—12-3-46.

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The Permanence of Termite Repellents[1]

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In addition to all the desirable qualities which cabinetmakers recognize in the wood of West Indian mahogany, *Swietenia mahagoni* L., for the tropics it possesses the characteristic of being highly resistant to termite attack, and more specifically, of being practically immune to attack by the West Indian dry-wood termite, *Cryptotermes brevis* Walker. Despite the high lignin content of mahogany heartwood, twice that of most temperate zone woods, it is doubtful if this is the decisive factor in its rejection by termites as an item of food, even though lignin is entirely undigestible by them. Indeed, when mahogany heartwood is eaten, ninety per cent of the weight of the wood eaten reappears in the weight of the excrement pellets, as compared with 50 per cent thus appearing when a more acceptable and more completely digestible wood has been eaten.

East Indian teakwood, *Tectona grandis* L., has an even higher lignin content than mahogany, and in addition contains considerable amounts of a specific chemical compound, a beta-methylanthraquinone called tectoquinone, which is definitely repellent to termites. In the extensive tests conducted with promising chemicals as repellents to the attack of the West Indian dry-wood termite, as reported in the *Caribbean Forester* for July 1943 and subsequently, tectoquinone proves to be among the most desirable, a 10-minute submersion of a very susceptible wood in a solution containing only 0.5 per cent of tectoquinone forming an effective protection against termite attack for as long as the tests have been conducted with it. Numerous other tropical woods are as unpalatable to dry-wood termites as are teakwood and mahogany, but of these woods, chemical analyses to determine the termite-resistant factor have not been made, or the constituent is not commercially available for test.

In striking contrast to the marked resistance or near immunity of many tropical woods to termite attack, all of those of the temperate zone which have been tested are susceptible or very susceptible, except two. The resistance of southern cypress, *Taxodium distichum* L., depends almost entirely on the extent to which its heartwood is impregnated with resinous gum, and to the fineness of grain; for coarse-grained, non-gummy cypress heart, wood is readily eaten, and the sapwood is very susceptible to attack by dry-wood termites. Osage orange, *Maclura* (or *Toxylon*) *pomiferum* Raf., is even more resistant to termite attack than mahogany and teak, but tests do not indicate that this is due to its high content of the dye fustic, which is its most obvious and characteristic constituent.

The high susceptibility to attack and destruction by the West Indian dry-wood termite, *Cryptotermes brevis* Walker, of the temperate zone woods commercially used for construction, interior trim and furniture, indicates the need for artificial protection of these woods if their maximum usefulness is to be obtained in the West Indies. Admittedly, no chemical and no method of treatment can so thoroughly impregnate any of these woods that to their very center they will be the equivalent of Osage orange, or West Indian mahogany, or Demerara greenheart, or Amazonian muirapiranga, or East Indian teak, or others of the equally valuable but less well-known tropical hardwoods. But by mere submersion in a water solution of copper sulfate or zinc chloride, one ounce of either to a gallon of water, it is possible to establish at least a thin outer layer of protection which will be effective as long as it remains entire and unbroken, or is not leached away by exposure to rainfall. Numerous termite-resistant chemicals, entirely insoluble in water, are readily dissolved in organic solvents, and in addition are more desirable because of greater ease of application and deeper penetration. Each of these chemicals must be evaluated according to its specific characteristics, and of these, possibly the most important is permanence.

Water itself, as well as the organic solvents, is temporarily repellent to dry-wood termites, but as soon as the water or other liquid evaporates from the piece of termite-susceptible wood used for the test, it at once becomes as susceptible to termite attack as though it had never been

[1] Paper presented on the Richmond Program, Dec. 1946.

submerged. Much slower to evaporate, or volatilize, but essentially not differing from water, alcohol, benzene or acetone in the way they eventually disappear from the wood sample, are ever so many other chemicals, solid as well as liquid, inorganic as well as organic. Possibly one of the most obvious is the bright red mercuric iodide, an inorganic solid, which dissolves in acetone to form a clear sparkling liquid, as transparent as the acetone itself. The color of the wood sample submerged in the solution of mercuric iodide changes to a light red as soon as the acetone has evaporated, indicating that the mercuric iodide has been precipitated on the wood in a very finely divided form. The treated sample is not only repellent to termites, but so immediately toxic that those resting on it, or attempting to run over it, die before they can get beyond the influence of the chemical. A few days later, however, and one will note that the wood samples impregnated with the greater dilutions of mercuric iodide no longer show any reddish coloration, and, placed with termites for test, are not toxic or even repellent, for the termites eat them with impunity. Within less than 2 months, even the samples impregnated with saturated solutions of mercuric iodide in acetone are similarly non-toxic and non-repellent. Indeed, so far as the termites are concerned, the effect of the mercuric iodide differs from that of water only in that a longer period elapses after submersion before the wood again becomes fit for them to eat.

In contrast to mercuric iodide is the action of some of the dyes normally present in some plants and woods, and synthetic dyes, some of which have been tested for their value as termite repellents. Some dyes are valueless, while others, such as alizarin, may delay the action of termites for several months. In all cases, the depth of coloration of the dyed sample has not changed at all, so far as one can see, thus one must conclude that the dye has not volatilized. Yet the termites can now eat the dyed sample, which, when freshly dyed, was immune from attack. So far as the termites are concerned, it makes little difference what the nature of this change is, for, if it is not evaporation or volatilization of the chemical, the result is the same.

Admittedly, mercuric iodide is an extreme case, chosen because we can see that volatilization has occurred, but experience tends to indicate that it is typical of numerous other organic compounds. Initially, the copper pyro and ortho phosphates (Monsanto) are 10 times as repellent to dry-wood termites as is copper sulfate, but within a year after treatment, *Cryptotermes* are able to eat the wood samples treated with 0.2 per cent of copper as copper pyro and ortho phosphate, although the 0.15 per cent of copper as copper sulfate-treated sample is still as repellent as when first prepared, 4 years ago. Indeed, even the organic triphenyl phosphate (see table 1) shows greater permanence.

One-tenth as much of the fluoride of copper, is as repellent as of the sulfate of copper, and, of the fluoride of zinc, one-tenth is as repellent as of the chloride of zinc. For the period during which these fluorides have been available for test (over a year and a half), the reaction of the termites to the wood samples impregnated with them has suffered no change, and one may assume that their effect is permanent. Indeed, on the basis of effectiveness in protecting wood against termite attack, the fluorides of copper and zinc might replace the standard chemicals. Their most obvious disadvantage (or advantage) is that they are not soluble in cold water, and not too readily soluble even in boiling water.

The silicofluorides of zinc (Harshaw) and copper, readily soluble in cold water, and the fluoborates, supplied in solution by the manufacturer (General Chemical) are at first as repellent as the fluorides, but in the course of several months' exposure in the air of the treated samples, only the zinc silicofluoride proved to be more, and the others even less so than the sulfate and the chloride.

The fluorides of cadmium and antimony are soluble in water, and the fluorides of mercury and lead in dilute nitric acid. Initially, they are more repellent to termites than any other compounds of these metals, and even the greatest dilution of cadmium fluoride tested was initially very toxic. Within a few weeks, however, the impregnations with mercuric fluoride no longer protect against termite attack; within a few months the concentrations of antimony trifluoride are less effective than

Table 1.—Days after submergence ten minutes in solution before attack by the West Indian drywood termite.

DILUTIONS (PER CENT) OF THE METAL	0.01	0.02	0.05	0.1	0.2	0.5	1	2	5
Copper fluoride	274	uneaten 30 months							
silicofluoride	3	9	14	63	173	—			
fluoborate	4	21	57	60	84	—			
Triphenyl phosphate	—	11	16	22	23	uneaten 16 months			
Copper orthophosphate	6	—	—	—	244	246	—		
pyrophosphate	8	—	—	—	240	244	—		
Zinc fluoride	279	uneaten 22 months							
silicofluoride	6	248	uneaten 14 months						
fluoborate	4	5	7	10	11	—			
Cadmium fluoride	6	12	128	142	146	—			
Lead fluoride	3	4	44	110	139	—			
fluoborate	3	4	5	6	7	—			
Mercuric iodide	—	14	28	56	59	—			
fluoride	4	15	24	60	—				
Antimony trifluoride	—	—	3	7	10	51	263	—	
Chromium fluoride	5	14	17	22	26	39	—		
Ferric fluoride	—	7	8	9	10	—			
Aluminum fluoride	—	—	—	—	2	21	—		

DILUTIONS (PER CENT) OF SUBSTANCE NAMED	0.01	0.02	0.05	0.1	0.2	0.5	1	2	5
Sodium fluorescein			2	3	4	5	6	—	
Fustic			2	7	9	10	13	14	—
Morin			5	6	7	8	—		
Malachite Green			8	13	14	20	—		
Alizarin in NaOH on flamboyán			8	46	68	82	95	—	
on almácigo	7	78	107	109	113	133	147	—	
2,3-dichlor-1,4-Naphthoquinone			3	16	33	74	77	117	—
alpha-Naphthaflavone			55	58	60	uneaten 16 months			
Xanthone			49	53	60	uneaten 16 months			
Tectoquinone			24	36	45	uneaten 16 months			
Naphthenates:									
Cadmium (12% uneaten in 2 years)						8	20	27	41
Zinc (12% uneaten in 2 years)						48	68	77	89
Lead (4% uneaten in 16 months)						18	28	150	
Copper (12% uneaten in 2 years)					10	28	150	152	154
Mercury (4% uneaten in 2 years)					49	56	58	121	
DDT			25	27	29	35	37	uneaten 33 mo.	
Benzene hexachloride (alpha & beta)			4	5	7	10	15	44	—
"Thanite" (Hercules Powder)			6	17	25	30	91	415	—
Isobornyl Thiocyanoacetate			28	41	43	132	233	—	
Chlorinated Terpenes			150	296	298	300	uneaten 14 months		
2,4-dichlor Phenoxyacetic Acid			—	5	11	15	21	123	—
Tetrachlorphenol			—	5	7	37	46	116 une. 18 mo.	
Pentachlorphenol			—	10	13	273	337	uneaten 32 mo.	
Hexachlorphenol			—	—	5	7	113	uneaten 32 mo.	
Pentabromophenol			—	—	5	14	uneaten 24 months		
Diphenyl Mercury			2	107	109	176	uneaten 18 months		
Phenylmercuric chloride			10	106	112	161	uneaten 18 months		
Triphenylstibine			—	15	18	45	uneaten 16 months		
Triphenyl phosphate			16	22	23	uneaten 16 months			
Pyridimercuric chloride			6	27	uneaten 12 months				
stearate			14	19	uneaten 12 months				
Pentachlorphenates:									
Sodium	—	14	22	25	uneaten in 22 months				
Lead	5	15	21	25	uneaten in 18 months				
Copper	27	42	108	111	uneaten in 2 years				
Zinc	18	21	155	235	uneaten in 19 months				
Dimethyldithiocarbamates:									
Ferric Iron "Fermate"				12	169	uneaten 34 months			
Copper				529:	readily eaten, ? toxic				
Zinc				530:	scantily eaten, toxic				

those of antimony trichloride, and the parallel concentration of lead fluoride is eaten; within half a year the termites are able to eat wood impregnated with stronger concentrations of cadmium fluoride than those with less cadmium as cadmium acetate and bromide.

Because some inorganic chemicals, as illustrated, become somewhat to very much less repellent to termite attack with the passage of time, it is necessary to test all of them repeatedly, to make sure that the results are as permanent as they seem at first. Regarding the organic compounds one soon comes to consider all results as temporary, and subject to change and correction as the period of the test is lengthened.

The chlorination or bromination of phenol, producing such effective treatments for the preservation of wood as pentachlorophenol, pentabromophenol and hexachlorophenol (Dow), is not a unique success, for the chlorinated terpenes (Hercules Powder) are initially very toxic to termites at great dilutions. Although these treated samples may be eaten after 5 months, the wood with the next greater concentrations is still toxic for another 5 months. Thus, despite their initial effectiveness, one can but hesitate in making any prediction as to the permanence of the chlorinated terpenes, for the various kinds and fractions of pine oil from which they are presumably derived have a very temporary effect in delaying termite attack. Chlorination of the resinous gum of cypress, or of oil of cedar, gives greater promise of permanence. Neither heavily chlorinated fractions of cashew nut shell oil, nor the unchlorinated crude, show a permanent value in repelling termites, but the chlorinated crude cardol (General Foods) continues to be effective for a year at a concentration of 5 per cent, and the chlorinated crude anacardic acid for even longer.

Theoretically, combinations of the repellent metals with toxic or repellent organic compounds should give maximum results, comparable to zinc and copper fluoride being more effective than zinc chloride and copper sulfate. The commercially available naphthenates of such metals (*Nuodex*), usually dark in color, sticky and evil-smelling in all cases, appeal to us as being the sort of thing that should be repellent to termites, as they are offensive to us. Tests show, however, that surprisingly high concentrations are ineffective, treatments containing 12 per cent being required to protect wood samples for 2 years.

Much pleasanter to handle are the metallic salts of pentachlorphenol, impregnations with 0.2 per cent having proved repellent for as long as they have been available for test. Sodium pentachlorphenate (Monsanto), water-soluble and readily obtained, surprisingly enough appears to be almost, if not quite, as effective as the pentachlorphenates of copper (Monsanto) zinc (Dow) and lead.

Ferric iron is a less powerfully repellent metal, and duPont's *Fermate*, a ferric dimethyl-dithiocarbamate, although somewhat toxic to termites at first, eventually fails to protect wood from their attack at concentrations of less than 0.5 per cent. Comparable combinations with copper and zinc are initially very toxic, so much so indeed that tests merely repelling termites can not be conducted. A year later, however, the wood samples are no longer violently toxic, and 4 months later at 0.1 per cent, neither chemical prevents the wood being eaten. The chloride and the stearate of pyridyl-mercury (Mallinckrodt) have proved to be equally repellent to termites during the short time they have been available for test, and somewhat more so than diphenyl mercury and phenylmercuric chloride, but the cost of all mercury compounds is so high by comparison with that of copper and zinc that it is doubtful if any of these will be commercially used for treating wood.

The graphs of resistance to termite attack displayed by the various organic chemicals at different concentrations do not show a uniform pattern. Thus, from past experience or similarity to other chemicals, one can not predict as to projections into the future. Of those of little or no value, such as the yellow dye sodium fluorescein, the lowest concentration tested is attacked on the day after the wood sample was impregnated, and each doubly greater concentration is eaten on the following day. More promising, but eventually disappointing, are those in which, although two or three of the lower concentrations show a somewhat similar pattern, attack may be delayed for weeks or months on the next greater concentration, as in the case of alizarin, and the

graph is continued on another plateau. But eventually the termites attack all the greater concentrations prepared for test.

Regardless of their start, the graphs of all the apparently valuable organic compounds eventually terminate in the infinity of a treated sample uneaten after a long period of exposure to termite attack. Most striking are pentabromophenol and DDT. Of the latter, 1 per cent protected treated wood for little more than a month, yet 2 per cent DDT is uneaten over 30 months later. Two weeks only did 0.5 per cent pentabromophenol protect treated wood, yet the sample impregnated with 1 per cent pentabromophenol is still uneaten by termites 2 years later. But with 0.1 per cent copper and zinc dimethyldithiocarbamate eaten after 529 and 530 days, 2 per cent *Thanite* after 412 days and 1 per cent pentachlorphenol after 337 days, it becomes obvious that the period of test must be for years, to be at all conclusive. No way of speeding up mere exposure in the air seems practical, yet it is impossible to continue tests indefinitely in time, to prove that somewhat or considerably greater concentrations will continue to be effective for 10 years, 20 years, or permanently. Actual commercial applications can not wait that long.

The results obtained experimentally, using the most susceptible woods for test samples, are, however, hardly more than an indication of what may be expected in practice with less susceptible commercial woods, for their natural resistance may be a rather considerable factor to be added to that of the chemical. At the start of the investigations, the wood of the almácigo or West Indian birch, *Bursera simaruba* L., was used because it was known to be very susceptible to termite attack, and a supply happened to be available for use. Later, when all the very susceptible woods were re-tested to determine which were the most susceptible, it was found that of those readily available in Puerto Rico, the flamboyán or royal poinciana, *Delonix regia* Boj., was considerably more susceptible to dry-wood termite attack than was almácigo. The difference was not great, for both were close to the bottom of the list, and it may seem a small point to emphasize, but the comparative tests with alizarin (see table 1) show how important it may be.

The wood of neither almácigo nor flamboyán has any commercial value, but they were invaluable when used for testing the chemicals because the results as obtained show largely the value of the chemical, with a minimum of resistance due to the wood used. For commercial woods, the value of the chemical will be somewhat to considerably increased by whatever greater natural resistance these woods possess, even if it is not much by comparison with mahogany. At least one can be certain that any treatment, using any of these more desirable chemicals, is infinitely better than if no attempt at protection had been made. One may reasonably hope and expect that impregnations of from two to five times as much as have given protection to such very susceptible woods as almácigo and flamboyán for a year or longer, should be effective on commercial woods for a considerable period of years. Definite proof of permanence, however, we can not obtain, and its too confident prediction is only wishful anticipation.

SUMMARY.—Of fluoride of copper, when used to impregnate termite-susceptible wood, one-tenth as much is as permanently repellent to the "polilla" or West Indian dry-wood termite, *Cryptotermes brevis* Walker, as of copper sulfate; of fluoride of zinc, one-tenth as much is as repellent as of zinc chloride. The silicofluorides of zinc and copper, their fluoborates, and the fluorides of cadmium lead, antimony and mercury, although initially as effective, and in some cases very toxic, eventually cease to be either repellent or toxic. The loss of this property of being repellent to termite attack applies to some inorganic chemicals impregnating wood at great dilutions, but was found to be universal among the organic compounds tested.

Wood dyed lavender with 0.05 per cent alizarin was thus protected from termite attack for over 3 months, but that dyed deeply purple with 1 per cent alizarin was eaten in less than 5 months. Diphenyl mercury and phenylmercuric chloride at 0.1 per cent made wood resistant for over 3 months, but impregnations with twice or five times as much protected the treated wood for only a few days longer. Other chemicals show very different reactions to the termites. Wood submerged in a 1 per cent solution of DDT in benzol was attacked by termites in little more

than a month's exposure to the air, but 2 per cent DDT has protected for nearly 3 years. Two weeks only did 0.5 per cent pentabromophenol protect, yet the sample impregnated with 1 per cent pentabromphenol is still uneaten by termites 2 years later. Tectoquinone at 0.2 per cent was effective for a month and a half, and 0.2 per cent xanthone for 2 months, but the wood samples submerged in 0.5 per cent of these chemicals have not been eaten in over a year. Dilutions of 0.1 per cent of the lead and sodium pentachlorphenates, and of pyridimercuric chloride and stearate, are eaten in less than a month, but 0.2 per cent of these chemicals has not been eaten in a year or longer.

As all tests were made on woods very susceptible to termite attack, the natural resistance of commercial woods, reinforced by that of the more effective organic compounds in large amounts, should result in at least commercially permanent immunity.—12-11-46.

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International Air Commerce and Plant Quarantine[1]

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To present a better picture of the phenomenal advancement of international air commerce and its relation to plant quarantine enforcement, it seems desirable to sketch briefly some of the historical background of this amazing new method of transportation.

DEVELOPMENT OF INTERCONTINENTAL AIR TRANSPORTATION.—With the first crossing of the Atlantic by the U. S. Navy's flying boat NC-4 in May 1919 providing the stimulus, commercial overseas air transportation was inaugurated by Pan American Airways between Havana, Cuba and Key West, Florida in 1927. Further rapid expansion of this service soon connected the two American continents and by 1933 intermittent air mail flights were being made across the So. Atlantic from Africa to Brazil. In 1935 regular commercial trans-Pacific air service was inaugurated between San Francisco and Hawaii, which by 1937 was extended to the Orient. By 1939 the North Atlantic was also being flown by regularly scheduled air transports. However, the most startling development of intercontinental air transportation took place shortly after our entry into World War II, when the military services of the United States and our allies began the ferrying of combat planes and equipment to all theatres of military operations. Within a few months they were virtually circling the globe. During the height of these operations in the latter part of 1945, the eastbound flights alone across the Pacific, had reached a volume of over 1400 planes a month, or an average of about one plane every 30 minutes around the clock.

RISK OF TRANSPORTING AGRICULTURAL PESTS BY AIRCRAFT.—Had no measures been taken to safeguard this immense volume of air traffic from the risk of transporting injurious insect pests and diseases from one continent to another, these planes and the thousands of passengers and crew members they carried could easily have introduced into this country many species of destructive pests not yet established here. As a matter of fact, in spite of our best efforts, it will be nothing short of a miracle if some destructive species are not found to have gained a foothold in this manner. If it were not for the cooperation of the Army, Navy, and the Public Health Service, through the guidance first of the Interdepartmental Quarantine Committee and subsequently

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of the designated quarantine liaison officers of those services, our task would be even more difficult. Nor can we say that we have the problem yet under control, for we still lack a sufficient number of adequately trained quarantine inspectors, proper facilities and equipment for effectively freeing aircraft from potential agricultural pests, and the means to conduct an adequate educational campaign to acquaint air travelers and carrier lines with the greatly-increased risk of transporting destructive pests and diseases from the far corners of the earth through this phenomenally fast method of transportation.

Most of us are familiar with the more publicized risk of introducing by aircraft certain insect vectors of human diseases, such as mosquitoes and flies. Although the risk of transporting those pests by air is probably greater than the risk of transporting agricultural pests, it must be remembered that mosquitoes and flies are rather easily killed by thoroughly treating the inclosed portions of a plane with an aerosol spray containing pyrethrins, DDT, and other compounds. While certain agricultural pests such as adult fruitflies, thrips, and even some lepidopterous adults, which might enter the cabin of a plane on the ground, would probably be eliminated by this aerosol treatment, the immature stages of these insects and most adult weevils, beetles, scales, mealybugs, and others are not so likely to be affected.

Although there are differences of opinion on the subject, there is good reason to believe that a pest which arrives with a host has a much greater opportunity to become established than one which arrives as a stowaway. Generally speaking, most specimens which gain access to the cabin of a plane and go along for the ride, so to speak, are not so much of a menace as one might think. If both sexes, or even gravid females, are present, they must first escape the aerosol treatment and then, upon arriving at destination, they must find their way out of the plane and locate suitable host plants near by on which to establish themselves. Most of the important air terminals, even in the tropics, do not have an abundant growth of host material in close proximity to the air strips. Furthermore, the risk of insects escaping from planes in flight or being carried long distances in a living condition, lodged in crevices or pockets on the exterior surfaces of aircraft is so remote as to be of no practical concern. However, please do not misunderstand me, I am not trying to minimize the risk of transporting insects by aircraft, but merely to emphasize that the greatest risk of introducing injurious agricultural pests lies in the rapid transportation by air of infested or infected host materials.

We have ample evidence of this risk. During the fiscal year ending June 30, 1945, 45,728 airplanes arriving from foreign countries and overseas possessions of the United States were inspected. Of this number, 7299 or approximately 15 per cent were found to be carrying prohibited plant material, much of which was of tropical and subtropical origin, and from which 2442 interceptions of insects and plant diseases were made. Among the more important insects taken from this material were the Mediterranean fruitfly *Ceratitis capitata* (Wied), the melon fly *Dacus Cucurbitae* (Coq), the Mexican fruitfly *Anastrepha ludens* (Loew), the West Indian fruitfly *Anastrepha mombinpraeoptons* (Sein), and several other species of *Anastrepha*, plus the pink bollworm of cotton, *Pectinophora gossypiella* (Saund), and other destructive pests.

There has been little change in the picture this year except for an increase in the number of planes inspected and in the volume of prohibited material intercepted. Injurious plant pests are repeatedly being intercepted from aircraft operated directly or under contract for the Army and Navy, despite rigid orders to all military personnel that the carrying of prohibited plant material on aircraft from outside the continental United States and our territories must be eliminated.

NECESSARY SAFEGUARDS.—Our most important safeguard against this risk, in my opinion, is the effective inspection of all arriving aircraft by adequately trained personnel, to remove and properly safeguard any prohibited or restricted host material which may be carried therein.

In addition to this, of course, an adequate insecticide treatment should be applied to all inclosed portions of the plane, preferably just after take-off and again just before landing. This treatment must be carefully applied and rigidly checked upon to assure its full effectiveness.

At this point may I call attention to the

urgent need for further research work in developing more effective insect eradication treatments and better methods of application. More effective insecticides and more suitable fumigants are needed. If possible, some sort of a conduit system should be provided by which these compounds may be liberated into all parts of a plane from one central location. The application of DDT or similar compounds to the interior surfaces of a plane, either by repeated sprayings or in paints or lacquers should be investigated. Studies might be made of the practicability of applying insect repellents to exterior plane surfaces. A suggestion has also been made that all vegetation in the vicinity of international airports be continually treated with DDT and other insecticides to prevent the establishment of any pests which may escape from arriving planes. In this connection I would further suggest that various types of insect traps be maintained in the vicinity of all important air terminals.

Obviously there are many important problems in this regard yet to be solved and, as said before, the need is urgent. The cooperation of the aircraft-production industry is essential, and its interest in this problem should be stimulated without delay.

Since, as previously indicated, the elimination of certain agricultural pests from aircraft is more difficult than the elimination of insect vectors of human diseases, and an effective treatment for the former would be a satisfactory safeguard against the latter, it seems only logical to suggest that the freeing of aircraft from insects is of greater concern to agricultural quarantine officers than to public health quarantine officials. This conclusion is shared by such competent observers as Captain T. B. Magath and Lieutenant Colonel P. T. Knies, formerly quarantine liaison officers of the Navy and Army, respectively. There should, of course, be close cooperation between the two agencies as far as international air commerce is concerned, at the same time preserving the primary purpose of air travel, which is SPEED. Any duplication of effort in this regard would only result in unnecessary delays to the arrival and departure of planes, passengers, and cargo.

While feeder lines will undoubtedly be developed, the main arteries of international air commerce will, for some time to come, follow the principal routes already opened up by the far-flung operations of the Army and Navy Air Transport Services. From the standpoint of the effective use of our limited inspection personnel, and to minimize the risk from too many avenues of entry for destructive new pests, an additional safeguard can be had by funneling our international air commerce through a limited number of airports of entry. Obviously this can be accomplished only if those interested are alert to the danger.

INTERNATIONAL AGREEMENTS FOR QUARANTINE CLEARANCE OF AIRCRAFT.—Within the past year or two there have been several conferences with representatives of foreign governments on the subject of international air commerce. These have covered such problems as international air routes, terminal privileges, passenger and cargo rates, safety requirements, and others. It is my hope that future conferences of this nature will give still further attention to the requirements of the so-called "border clearance" agencies, which include public health and agricultural quarantine, customs, and immigration.

Much better safeguards against the transmission of pests by air from foreign areas could be provided, and with a more economic and effective use of manpower, by locating inspection forces at certain strategic air terminals in foreign countries for the clearance of inbound planes and passengers. This would likewise expedite the debarkation of passengers and cargo upon arrival at airport terminals in this country. To establish such a procedure it would be necessary to coordinate the activities of all the border clearance agencies, which might prove difficult, but in my opinion the advantages are of sufficient importance to justify every effort being expended toward that end. This is another subject that has been receiving favorable consideration at the international conferences on civil aviation.

From a plant-quarantine standpoint, we are convinced of its practicability, for, other than the limited number of planes using the Aleutian route, most military and commercial air transports crossing the Pacific funnel through two airports in Hawaii, at which we maintain plant quarantine inspection service on a twenty-four hour basis. All eastbound planes and pas-

sengers are examined there with an inspection force considerably smaller than would be required to provide comparable inspection at the seven terminals in California now handling these trans-Pacific arrivals. A similar procedure has also been set up for the Aleutian route through the recent assignment of Bureau inspectors to the air terminals at Fairbanks and Anchorage, Alaska, where inspections are made of aircraft and passenger baggage arriving from the Orient.

While the extension of this procedure to strategic terminals in certain foreign countries—Canada, Mexico, Cuba, Bermuda, and other locations even farther distant, would require the consummation of agreements with the countries involved, it is believed that this would not present an insurmountable problem. Obviously, such arrangements would have to be made on a reciprocal basis, but there seems no need for hesitancy on our part in encouraging other nations to avail themselves of a like privilege. I further believe that the international air-transport lines would strongly favor such an arrangement because of the opportunity it affords of expediting the movement of their traffic. The proven advantage of better protection from pests with a smaller inspection force would be as applicable to this traffic as it is on the trans-Pacific routes through Hawaii and Alaska.

In conclusion, it seems desirable to point out that the speed with which an insect pest or plant disease can now be transported great distances to a new environment by modern aircraft has demonstrated the weakness of relying upon quarantine inspectors at ports of entry in this country as our sole line of defense against the introduction of injurious plant pests. In my opinion, our defense should be deepened to include at least three lines instead of one. Our outer defense should consist of periodical pest surveys in those foreign countries from which we import plants or unprocessed plant products, so that we may become more familiar with the destructive species likely to be transported and therefore better equipped to safeguard agaist their entry. Our second line of defense should, of course, comprise the inspection and safeguarding of agricultural imports at the ports of entry as now instituted. Still a third line of defense should consist of continual surveys in the vicinity of ports of entry to spot, at the earliest moment, the establishment of any new pests which may have filtered through our outer defenses.

It is hoped that the members of this Association and all others who are interested in the efforts being expended to build and maintain an effective defense against the further introduction of destructive plant pests, will study this problem, and not only give us the benefit of their suggestions, but the support that will be needed to extend this system of defense to meet adequately the greatly increased hazard of pest introduction which modern developments in intercontinental air transportation have laid on our doorstep.—11-16-46.

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Dr. Stanley J. Carpenter who, after his release from the army, was employed by the National Biscuit Company, has joined the staff of the New Jersey Agricultural Experiment Station at New Brunswick, N. J.

SCIENTIFIC NOTES

Results with Benzene Hexachloride

W. C. O'KANE, *New Hampshire Agricultural Station, Durham*

Early in 1945, in exploring various chlorinated ring compounds at the New Hampshire Agricultural Experiment Station, a chemical was found which gave impressive performance. The exploratory technique was the procedure in regular use at the New Hampshire station, in a search for contact insecticides. A 5 per cent solution of a compound in household spray kerosene (*Ultrasene*) is atomized under controlled conditions on caged 5-day-old houseflies. Dosage and other factors are so adjusted as to give 50 per cent kill with 5 per cent *Lethane 384 Special*. The compound in question gave 100 per cent kill at 5 per cent concentration.

The following day this compound was again tested at concentrations of 5, 4, 3, 2, and 1 per cent. It still gave 100 per cent kill. In further tests concentration was reduced to as little as 0.1 per cent. This gave less than complete kill, but a concentration of 0.25 per cent gave 100 per cent dead.

The compound giving this high performance was benzene hexachloride, also designated as 1, 2, 3, 4, 5, 6 hexachlorocyclohexane.

Work on this material was immediately intensified and extended, and has continued to occupy major attention ever since, with several entomologists and technicians occupied in its study.

A short time after the compound was first uncovered we received an advance copy of extracts from an address delivered before the Liverpool, England, section of the Society of Chemical Industry, by Dr. R. E. Slade, on *A New British Insecticide*, giving various interesting and important data concerning benzene hexachloride and its isomers. Subsequently, a complete copy of Doctor Slade's address became available, through its publication in October 1945 in *Chemistry and Industry*. Since the work of Doctor Slade and his associates began long before our own, we can hardly make any claim, but there is some satisfaction in having made the discovery on our own.

Throughout our work we have enjoyed the active collaboration of research chemists in the laboratories of Commercial Solvents Corporation, at Terre Haute, Indiana. The first sample submitted to us was prepared by these chemists. Subsequent work in the isolation of isomers, and many other important details, are to be credited to the laboratories of this organization.

Since benzene hexachloride is a solid, substantially insoluble in water, and since it has an appreciable vapor pressure, much of our work on insects has been done with dusts prepared by micropulverizing the compound with pyrophyllite (*Pyrax ABB*), and with some other inerts. The finished dusts contained 0.5 or 1.0 per cent gamma isomer and are referred to in this paper with appropriate gamma designations. Much less work has been done with suspensions of the dry material in water, using wettable powder containing 25 per cent benzene hexachloride (2.5 per cent gamma isomer). Considerable work has been done with a liquid concentrate containing approximately 1.5 per cent gamma isomer.

The preliminary results that follow represent largely work performed by our own staff, but in part experiments in other areas, carried on at our suggestion and evaluated by competent entomologists.

Table 1.—Preliminary tests with benzene hexachloride to control various insects. Except where noted the gamma isomer at 0.5 per cent strength was used.

INSECT	SUMMARY OF TREATMENT AND RESULTS
Colorado potato beetle	0.5% dust, one application, 16 to 30 pounds per acre. All larvae and adults killed. Wettable powder as a spray; 0.05 and 0.075 pound per hundred gallons; equivalent to 10 to 15 pounds dust per acre. Killed 70 to 100% of larvae and adults.
Potato flea beetle	Dust: One application; 20 to 30 pounds per acre. Complete kill. Wettable powder; spray; 0.5 and 0.075 lb. gamma per 100 gallons: Killed 70 to 100%. Results better with 0.075% strength.
Three-lined potato beetle (Larvae)	Dust, one application, 40 lbs. per acre gave complete control.
Potato leaf hopper	Dusts, 20 to 30 pounds per acre, one to five applications: Kill in general unsatisfactory.
The aphids *Myzus persicae*, *Macrosiphum solanifolii* and *Aphis abbreviata* on potato	Five applications of spray with wettable powder 0.075 pound gamma per 100 gallons. Aphid count from 50 lower leaves, 158 as compared with 1497 from plots sprayed with calcium arsenate. Five applications of the dust gave only 25 aphids per 50 lower leaves.
Imported cabbage worm	Two or more applications; dust; 25 to 60 lbs. per acre. Kills of 70 to 100% recorded.
Cabbage aphid	One application of the dust: Complete control.
Cabbage looper	One or more applications of dust; 30 lbs. per acre. Complete control observed.
Striped cucumber beetle	Both 0.5 and 0.25% strengths: One or more dust applications: Insect readily controlled.
Onion thrips. (On onions)	One dust application; 50 to 60 lbs. per acre. Approximately complete control. Presence of dew advantageous.
Asparagus beetle	One application of the dust gave complete control.
Spinach flea beetle	Readily killed with 0.25% dust.
Squash bug	One application; dust at 35 lbs. per acre when runners were 2 to 3 feet long. Nearly complete control of nymphs: Considerable kill of adults.
Mexican bean beetle	One or more dust applications. Unsatisfactory results with larvae.
Onion thrips (On tomatoes)	Severe infestation over a large commercial area. One application of dust at 40 lbs. per acre, followed in 10 days by one application at 30 lbs. per acre. Approximately complete control.
Garden fleahopper (On tomatoes)	One application of dust. Apparently complete control.

Table 1. (*Continued*)

Insect	Summary of Treatment and Results
Corn earworm	One application of dust directed toward silks. No infestation on treated ears. Larvae present on untreated ears.
Rice weevil (Attacking mature corn ears in the field)	One application of dust directed at the silks. No weevils in dusted ears. Untreated ears heavily infested.
Greenhouse whitefly.	One or more dust applications. Adults apparently killed but nymphs are resistant.
Greenhouse leaf tier	One treatment with dust. Complete kill of larvae and adults. Larvae not reached by the dust killed by vapor stage.
Gladiolus thrips	One application of dust. Complete control.
Thrips on lilac (sp.?)	One application of dust. Complete control.
Elm leaf beetle	One application of dust. Complete control.
Leconte's sawfly larvae	One application of dust. Complete control.
Corythuca pergandei Heid., nymphs and adults	One application of the dust gave complete control.
European elm scale	One application of the standard dust. Complete control.
Spiny elm caterpillar	One application of the standard dust. Good control.
Cottonwood leaf beetle; larvae on willow	One application of dust; good control.
Spiraea aphid	One application of standard dust. About 80% control.
Fall webworm	One dust application. Satisfactory control if dust is in contact with the larvae.
Japanese beetles	Marked repellency observed; adults confined on dusted plants died.
Grasshoppers (*Melanoplus* spp.)	One application of dust at 60 lbs. per acre. Complete control of late instar nymphs.
Hairy chinch bug	One application of 4% dust at 50 lbs. per acre. Complete control.
Ants (Several species living in soil)	Standard dust. One application to surface of soil. Good control.
Apple aphid	Three applications of standard dust gave 90% control.
Black cherry aphid	One application of dust gave complete control.
Striped flea beetle	Easily killed with standard dust.
American cockroach	Dusts used at 0.5 and 1.0%; one or more applications. Good control. Roaches driven out of cracks by 1.0% strength.
Mosquito larvae (*Aedes* spp. and *A. aegypti*)	One application of the dust on surface of water at 10 lbs. per acre. Apparently 100% control.

Table 1. (*Continued*)

Insect	Summary of Treatment and Results
Head louse	One application of 1% dust reported effective in one application by a New Hampshire doctor and a district nurse. Head of patient bound in a towel for 2 or 3 hours. Irritation by lice ceased in 20 minutes.
Predaceous Coccinellidae	Apparently resistant since many were observed to survive field applications of the standard dusts and since no dead beetles were found.

FLAVOR.—Crude benzene hexachloride may cause objectionable flavor in some food products.

Potatoes are susceptible. Either soil conditions, or variety, or both, may have an influence. While no off-flavor was in evidence in some tests, unpleasant flavor was present in others.

Peas developed a bitter flavor in various tests.

String beans may show no undesirable flavor if applications are spaced far enough apart, and if sufficient time elapses between the last application and picking, but under other conditions an off-flavor is evident.

In large-scale tests tomatoes developed no objectionable flavor with two applications spaced 10 days apart. A larger number of applications may cause some undesirable flavor, though liability seems not to be great.

Bell peppers appear to be in the same category as tomatoes.

Sweet corn developed a trace of undesirable flavor after several dustings.

Cucumbers showed no off-flavor with as many as five applications.

Strawberries developed no unpleasant flavor with as many as nine applications spaced a week apart.

Cabbage, onions, and carrots have exhibited no off-flavor.

Early season applications on squash and melons have produced no undesirable flavor.

No applications have been made on tree fruits.

Dipping in Benzene Hexachloride to Control *Amblyomma americanum*

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During the 1946 season dipping tests were conducted to determine the effectiveness of benzene hexachloride for the control of the lone star tick, *Amblyomma americanum*, attacking stock animals on the Bright Elbow Ranch, Protem, Missouri. Purebred Hereford show animals were used in these tests. The ranch is located in the Missouri Ozarks where the lone star tick is a major pest during the growing season.

EQUIPMENT AND MATERIALS.—The first application was sprayed with a 500-pound pressure machine. The legs and undersides of the animals were wetted by a six-nozzle underline spray while the backs were sprayed with a four-nozzle broom. The five later applications were accomplished by dipping.

The test solutions were prepared from a 50 per cent wettable power containing 10 to 13 per cent gamma isomer.

PROCEDURE.—By mopping some dry milk cow it was found that a 1 per cent solution would kill the ticks on the animals and protect them from being attacked for 7 days in spite of the frequent showers.

The animals were sprayed on April 16 with a 1 per cent benezene hexachloride solution. They were dipped in a 0.25 per cent solution on April 30. The later dippings on May 14 and 28, and June 25 contained a 0.5 per cent concentration.

The results of the applications were somewhat screened because of the frequent rains which fell immediately following the treatments; on April 16, 0.58 inch of rain fell, on April 30, 0.51, on May 16, 2.71, on May 31, 1.79 and on June 26, 0.75 inch. In July, August and September an extremely dry period existed and the ticks, except for the larvae, disappeared for the summer.

Before the tests were started a 10 day old Hereford calf was force-fed about 5 milliliters of a 1 per cent solution. This amount was thought to be the quantity a calf might get when sucking a dipped animal. There was no apparent effect on the calf other than an increased appetite. The solution may have caused a slight irritation in the stomach.

RESULTS AND CONCLUSIONS.—The sprayed application gave a good kill and no live ticks were found for 7 days where the animals were thoroughly wetted. It was 10 days before the tick population began to build up again. The 0.25 per cent dip was too weak to kill any of the ticks. The rain was probably responsible for the complete failure. The other dippings in spite of the rain gave protection from seven to ten days.

When the animals were driven from the pasture to be sprayed on April 16, they were covered with horn flies and one bull was carrying about 100 horse flies. The spray probably killed out the horse flies as they were not seen in numbers again during the later treatments. The number of hornflies was greatly reduced and in observing the treated with some untreated animals in the pasture, the treated ones were seen to be much more quiet. This fall the treated animals seemed to be in a much better condition, but no weighings were made.

Mopping dairy animals with a 0.5 per cent solution immediately following a milking, for the control of the lone star tick, imparted no odor or taste to the milk from later milkings. The treated areas received the same protection from the ticks as did the dipped stock animals.

SUMMARY.—A 0.5 per cent solution prepared from a 50 per cent wettable benzene hexachloride powder containing 10 to 13 per cent gamma isomer will kill all forms of the lone star tick and protect the treated animals for 7 to 10 days. Dipping gives better coverage and is faster than using a pressure sprayer when treating range cattle.—12-14-46.

Experiments in 1946 on the Control of Bugs that Cause Deformed Peaches

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Experiments conducted in 1944 and 1945 (Snapp 1946) showed that good control of sucking bugs that cause deformed peaches can be expected from dusting or spraying with DDT. The purpose of this paper is to report the results of further experiments on the control of these bugs, as well as of investigations to determine the insects that may be responsible for the deforming of peaches in South Carolina.

In 1945 a single application of DDT when the trees were in full bloom reduced the number of peaches injured by sucking bugs from 42.4 per cent to 7.8 per cent in South Carolina. The experiments in 1946 were conducted chiefly to determine the relative value of pre-blossom, petal-fall, and shuck-off applications of DDT and combinations of them for plant bug control. Sabadilla and benzene hexachloride were included in the 1946 experiments.

The experiments were conducted in a 4-year-old Burnett peach orchard at Spartanburg, S. C. According to the owner's estimate, from 40 to 50 per cent of the peaches from this orchard showed plant bug injury (Fig. 1) in 1945.

There were 9 unreplicated plots averating about 200 trees each. One pound of DDT, mixed and micronized with an equal weight of pyrophyllite, and one pint of fish-glue solution (1 pound per gallon of water) was used with each 100 gallons of spray. The benzene hexachloride was in the form of a wettable powder containing 31.6 per cent of benzene hexachloride reported to contain 12 per cent of the gamma isomer. The sabadilla was a wettable powder containing about 50 per cent of sabadilla seed. All sprays were applied with a 400-gallon sprayer, with power take-off from a tractor. Four-nozzle brooms were used on spray rods for applying the sprays at 400 pounds pressure, and from 1 to 2 gallons of spray was applied per tree, depending on the foliage and fruit development.

After the adequacy of the sampling procedure had been determined, 50 peaches on each of 10 trees in each plot were examined just before the harvest, June 18 to 21, to determine the percentage damaged by sucking bugs. The results are summarized in table 1.

Table 1.—Summary of results of orchard experiments on the control of sucking bugs attacking peaches at Spartanburg, S. C., during 1946.

SPRAY MATERIAL (QUANTITIES PER 100 GAL.)	TIME OF APPLICATION	PEACHES DAMAGED BY SUCKING BUGS
		Per Cent
DDT 1 lb.	Preblossom	23.4
	Full bloom	14.0
	Petal fall	9.6
	Shuck off	16.2
	Prebloom, petal fall, and shuck off	7.2
	Petal fall and shuck off	6.2
Sabadilla 1 lb.	Full bloom	29.6
Benzene hexachloride 0.33 lbs.	Full bloom	18.4
Check (untreated)	———	40.0

An analysis of the data shows significant differences between percentages of injury in the treated and untreated blocks, and between those in certain of the treatments. The plot that received DDT at petal fall and shuck off yielded the lowest percentage of injured peaches, but not significantly lower than plots receiving three applications of this insecticide, at pre-blossom, petal fall, and shuck off, or a single application at petal fall. A single pre-blossom application of DDT appeared less effective than a single application at full bloom or at petal fall. The results from the single application at shuck off suggested the possibility that some injury from sucking bugs oc-

[1] In cooperation with the South Carolina Peach Growers Association and the Clemson Agricultural College and South Carolina Agricultural Experiment Station.

FIG. 1.—Peaches damaged by plant bugs.

curred after shuck off. Jarring records indicate that pentatomids are most likely to have caused this injury. An application at petal fall would be preferable to one at full bloom, in order to avoid any possible ill effect of the treatment on insect pollinators, even though insects do not play an important part in the pollination of the peach.

Benzene hexachloride shows promise for the control of sucking bugs attacking peaches, although it was a little less effective than DDT. The difference was not significant. The benzene hexachloride applied at full bloom did not affect the flavor of the fruit at harvest. Sabadilla appeared to be comparatively ineffective.

A number of the trees in an untreated part of the orchard were jarred on March 7, when about 5 per cent of the blossoms were open; on March 15, when the trees were in full bloom; and on March 21, when about 85 per cent of the petals had fallen. No plant bugs were caught on March 7 or 15, owing to unfavorable weather, but shortly after sunrise on the cool morning of March 21 tarnished plant bugs were taken from every tree jarred. Although a moderate wind prevailed at times, as many as eight tarnished plant bugs were taken from a single tree and no less than three from any tree, with an average of more than five per tree.

No pentatomids or sucking bugs other than tarnished plant bugs were taken by jarring on March 7, 15, or 21, but when a number of the trees in the same plot were jarred shortly after sun-up on April 4, after practically all of the shucks were off, tarnished plant bugs had decreased to an average of but 0.25 per tree. However, at that time an average of 0.42 pentatomids per tree showed up. Jarring records in 1944 showed that large numbers of tarnished plant bugs were on peach trees in Spartanburg County orchards from full bloom until petal fall, after which they apparently left for other hosts. The species of pentatomids caught by jarring on April 4, 1946, were *Thyanta custator* (F.), *Euschistus servus* (Say), and *Brochymena quadripustulata* (F.).[2] The mirids jarred from the trees on March 21 and April 4 were the tarnished plant bug, *Lygus oblineatus* (Say).[2]

Considerable jarring was done in the same block on May 16, at a time when the stone of the fruit was practically hardened, but neither tarnished plant bugs nor pentatomids were found.

SUMMARY.—Two applications of DDT, at petal fall and at shuck off, appeared to reduce the number of peaches injured by plant bugs from 40 per cent to 6.2 per cent. There was no significant difference in the results from that treatment and three applications of DDT, at pre-blossom, petal fall, and shuck off, or from a single application at petal fall. A single application of DDT at pre-blossom was not so effective as a single application at full bloom or at petal fall. The results indicate that some injury, which may be caused by pentatomids, occurs after shuck off. Sabadilla applied at full bloom was ineffective, but benzene hexachloride showed promise.

Tarnished plant bugs, *Lygus oblineatus* (Say), were taken from every tree jarred when about 85 per cent of the petals had fallen. Their numbers decreased to a very low level when practically all the shucks were off, but at that time pentatomids showed up in small numbers. Neither tarnished plant bugs nor pentatomids were found when the peach stone was practically hardened.—12-12-46.

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Control of Stored Food Insects with Benzene Hexachloride

STANLEY J. CARPENTER

Many reports have been published during recent months on the use of benzene hexachloride ($C_6H_6Cl_6$) against insects of agricultural, industrial, household and medical importance. Benzene hexachloride is now known to be even more effective against certain insects than DDT.

The writer has been interested in determining whether benzene hexachloride can be used effectively against insects affecting stored food products, and preliminary laboratory tests have already been made with this insecticide[1] against the following insects: *Tribolium confusum* Duv., larvae and adults *Tribolium castaneum* (Herbst), adults; *Tribolium madens* (Charp.), adults; *Gnathocerus cornutus* (Fabr.), adults; *Oryzaephilus surinamensis* (L.), adults; *Tenebroides mauritanicus* (L.), adults; *Sitophilus oryza* (L.), adults; *Attagenus piceus* (Oliv.), larvae and adults; *Dermestes vulpinus* (Fabr.), larvae and adults.

These tests were made in wooden boxes which had been lightly sprayed with the insecticide approximately one hour before the specimens were introduced. All of the specimens began showing similar reactions of distress and loss of coordination of leg movements within 10 to 15 minutes after being introduced into the boxes. Insects were generally unable to crawl up the vertical sides of the test box after 30 minutes of exposure to the treated surface and the time required for death to take place varied from 4.5 to 24 hours. The only significant difference noted in killing time was for *Sitophilus oryza* which was considerably longer than for other species used in the tests.

Thirty adult specimens of *Tribolium confusum* were introduced on November 25 into a test box which had been treated with benzene hexachloride

[2] These species were determined by R. I. Sailer, Division of Insect Identification, Bureau of Ent. and Pl. Quar.

[1] The insecticide used in these experiments contains 10% of a 20 to 1 concentrate of benzene hexachloride and 5% of a standardized No. 20 pyrethrum extract in deodorized kerosene. The spray contains 0.15% of the gamma isomer.

on October 1. All the insects showed signs of distress and loss of coordination of leg movements within 15 minutes; after an hour none of the insects was able to crawl up the vertical sides of the box; and after 24 hours 14 were dead and the remaining 16 specimens were able to make only weak uncoordinated leg movements.

Adult specimens of *Oryzaephilus surinamensis* and larval and adult specimens of *Tribolium confusum* were planted in specimen boxes at different levels in a room and exposed to a smoke of the gamma isomer of benzene hexachloride. In this test, technical grade benzene hexachloride containing approximately 12 per cent of the gamma isomer was used at the rate of 50 grams per 1000 cu. ft. of room space. After 24 hours exposure all the insects were alive and appeared normal.

When benzene hexachloride was used as a "smoke" the odor persisted much longer than when it was used as a spray; however, no odor or taste of benzene hexachloride carried over into bread made of flour exposed to the smoke or spray. When benzene hexachloride is used in the form of a spray in localized areas where infestations of stored food insects exist in bakeries and other food handling establishments it is not expected to be particularly obnoxious.

These preliminary tests indicate that a spray containing benzene hexachloride may possibly be used effectively against some of the common stored food insects in food processing plants and in warehouses; however, it will be necessary to conduct extensive confirmatory tests within the plants to fully evaluate it. The writer is now conducting tests with benzene hexachloride against chronic infestations of *Tribolium* spp. in bakeries.—1-7-47.

Hexachlorocyclohexane Dusts and Fogs to Control Grasshoppers[1]

ROSCOE E. HILL and EPHRIAM HIXSON, *Department of Entomology, College of Agriculture, University of Nebraska,*[2] *Lincoln*

Exceptionally promising results were obtained with 1, 2, 3, 4, 5, 6-hexachlorocyclohexane (popularly known as benzene hexachloride) for the control of grasshoppers in Nebraska during the summer of 1946. This insecticide was applied in dust form with rotary hand guns, a power dusting machine, an airplane, and as a fog produced with a thermal fog machine. All experiments were conducted at the Scotts Bluff Experiment Station located in the irrigated section of the North Platte Valley near Mitchell, Nebraska. Collections made in mid-August showed that 98 per cent of the grasshopper population consisted of the following four species: *Melanoplus differentialis* (Thos.), *M. femur-rubrum* (Deg.), *M. bivittatus* (Say), and *M. mexicanus mexicanus* (Sauss.).

MATERIALS USED.—Small experimental lots of hexachlorocyclohexane dusts and wettable powders containing various percentages of the gamma isomer were obtained from several sources.[3] The dusts were used as received or further diluted with pyrophyllite to contain 0.58, 1, 1.15, 2 or 5 per cent of the gamma isomer when the tests were made in the field. For the fog, 5 pounds of a wettable product containing 5 per cent gamma isomer were used in 10 gallons of water.

EXPERIMENTAL RESULTS.—On the evening of July 16 a rotary hand-operated dust gun was used to "float" a hexachlorocyclohexane dust containing 0.58 per cent of the gamma isomer through a strip of alfalfa and weeds. This strip (4 feet wide and 20 feet long), upon which many grasshoppers were resting, was dusted at the rate of about 45 pounds per acre. The next morning 875 dead or nearly dead nymphs (no adults yet present) were found in a ditch immediately adjacent to the dusted area. Of these, 275 were collected and observed for possible survival in the insectary but only three subsequently recovered. The estimated kill in this instance was 95 per cent.

FIG. 1.—Applying hexachlorocyclohexane dust with a single-outlet orchard-type power duster for the control of grasshoppers.

In a similar test 0.58 and 5 per cent gamma dusts were again applied by hand at a rate of about 45 pounds per acre to small, somewhat isolated, plots of weedy alfalfa. Kills of 70 and 95 per cent respectively were obtained. Many grasshoppers which subsequently moved into the area dusted with the 5 per cent dust were found dying 2 and 3 days following application—the residue on the plants apparently remaining effective.

A fog produced with a *Bes Kil* machine was used in a third experiment on the evening of July 21. The machine was pulled behind a tractor at a speed of about 2 miles per hour, and 9 gallons of the concentrate (formula as above) were fogged onto three uncut strips of alfalfa. Each strip was 5 feet wide and the three totalled about 0.75 mile in length. Untreated check strips were alternated with the treated. Counts of the number of dead grasshoppers per square foot were taken 15 hours following application, averaging for the three treated plots: 16.0, 29.0, and 33.8; and for the untreated areas: 1.8, 0.6, and 4.2. Approximately 85 per cent control was obtained with the fog.

In a fourth test the applications were made with a single outlet orchard-type power duster (Fig. 1). Early in the morning of August 21, dusts containing 1, 2 and 5 per cent gamma isomer were applied on 2-acre blocks of alfalfa at the rate of approximately 25 pounds per acre. The results are summarized in table 1.

One, 1.15 and 5 per cent dusts were also applied by airplane. Since relatively small amounts of the dusts were available, and since it proved necessary to fly over an area having a heavy surrounding infestation, it was difficult to estimate the percentage kill with any degree of accuracy. Furthermore, it was neces-

[1] Published with the approval of the Director as paper No. 403, Journal Series, Nebraska Agricultural Experiment Station.

[2] Acknowledgment is made of the field assistance of Mr. Jack W. Lomax.

[3] Dow Chemical Company, Midland, Michigan; E. I. DuPont de Nemours & Company, Wilmington, Delaware; Niagara Sprayer & Chemical Company, Middleport, New York; Pennsylvania Salt Manufacturing Company, Philadelphia 7, Pennsylvania.

Table 1.—Effects of hexachlorocyclohexane dusts on grasshoppers in western Nebraska alfalfa fields.[1]

Per Cent[2] Gamma Isomer in Dusts	Pounds Gamma Isomer Per Acre	Grasshoppers per 100 Sweeps of Net,[3] Average— Before Dusting	15 Hours Following Dusting	24 Hours Following Dusting
1	0.25	138	26	3
2	0.50	128	2	1
5	1.25	266	21	5

[1] Dusts applied with orchard-type powder duster.
[2] Mixtures furnished by the Dow Chemical Company, Midland, Michigan.
[3] Night collections taken after dark and before sunrise (between 4:30 and 5:00 A.M.); thus at a time when the grasshoppers were sluggish and easily captured.

sary to use the plane under poor dusting conditions of mid-day. However, it appeared evident that hexachlorocyclohexane dusts could be applied effectively by airplane under favorable circumstances.

DISCUSSION AND CONCLUSION.—These tests indicate that hexachlorocyclohexane is an effective insecticide for controlling grasshoppers when used either as a dust or fog. All four species and all developmental stages of the grasshoppers involved were equally susceptible to this insecticide. In the insectary, undusted grasshoppers crawling over and feeding on dusted foliage were affected in 8 minutes. Usually large numbers were down on the ground in the field experiments 3 hours following exposure. Because hexachlorocyclohexane remains effective in the field for at least 2 or 3 days, any grasshoppers escaping death at the time of dusting may later obtain a lethal dose when they return to the foliage to feed or rest. In one field observation, 1.15 and 5 per cent gamma hexachlorocyclohexane dusts were killing grasshoppers 6 days after application.

The use of an insecticide such as hexachlorocyclohexane in dust, fog or spray form for grasshoppers would under many conditions be far more practical than baiting. Baits must be eaten to be effective and the conditions conductive to feeding on baits are often lacking in many grasshopper environments. For example, in Nebraska it is especially difficult to obtain satisfactory grasshopper control with baits in seed-alfalfa fields. Potato growers in dry-land farm areas likewise have experienced difficulty and have long needed a material which could be used as a dust or spray.

Dusts containing 1 or 2 per cent of the gamma isomer when applied at rates of 25 to 30 pounds per acre caused no visible injury to alfalfa, corn or potatoes. However, a 5 per cent dust (and a 2 per cent dust when applied too heavily) produced a definite chlorosis of potato foliage. Further observations regarding the phytotoxic effects of this material are needed.—12-3-46.

Dusts and Sprays for Grasshopper Control

G. M. LIST and J. L. HOERNER, *Colorado Experiment Station, Fort Collins*

It has long been recognized that under many conditions we need grasshopper controls more effective than the standard baits. This is especially true under irrigation where much of the breeding takes place on ditch banks and comparatively small population may do serious damage to intensively grown special crops.

During the month of September some of the recently developed insecticides were tested against adult grasshoppers. The insecticides were applied by airplane, hand duster, and power sprayers. The size of the treated plots varied from 10 acres to a half-acre. The grasshoppers in the tests were mostly the two-striped, differential, and red-legged species. They averaged about six grasshoppers, all species, per square yard.

The hexachlorocyclohexane used in preparing the dust contained 10 per cent of the gamma isomer. The dusts were applied to give rates of 1, 2, 2.5 and 3 pounds of hexachlorocyclohexane per acre.

A sample of the wettable powder used (later named *Toxaphene*[1]) did not give the percentage of active ingredients and was labeled "for experimental use only." The mixed dust contained 20 per cent of the material as it came from the container and was applied at a rate that gave 3 pounds of the concentrate to the acre. As a spray the material was applied at the rate 2 pounds per acre in 50 gallons of water.

The *Chlordane*[2] and *Colorado 9*[3] when used as sprays were first dissolved in xylene at the rate of one pound to one quart of the solvent with 50 cc. of *Triton 100* emulsifier added. This was then diluted with 50 gallons of water and applied to one acre.

The percentage of control was estimated and in most instances was verified by sweeping with a standard 15-inch net.

The insecticides tested and results recorded are as follows:

	Per cent control 8 days
Applied with hand duster	
Chlordane (5 per cent in pyrophyllite) 1 lb. per acre	98
Hexachlorocyclohexane (10 per cent in pyrophyllite) 2 lbs. per acre	90
Hexachlorocyclohexane (10 per cent in pyrophyllite) 3 lbs. per acre	96
Hexachlorocyclohexane (5 per cent in pyrophyllite) 2.5 lbs. per acre	98
DDT (25 per cent in pyrophyllite) 5 lbs. per acre	50
Toxaphane (Hercules Powder Co. product 20 per cent in pyrophyllite) 3 lbs. per acre	95
Trichlorothane[4] (10 per cent in pyrophyllite) 1.5 lbs. per acre	95
Sprays	
Chlordane, 1 lb. per acre	98
Colorado 9, 1 lb. per acre	40
Toxaphene, 2 lbs. per acre	95
Applied as dust by airplane	
Chlordane (5 per cent in pyrophyllite) 1 lb. per acre	80
Hexachlorocyclohexane (5 per cent in pyrophyllite) 1 lb. per acre	40

The *Toxaphene* hexachlorocyclohexane, and *Velsicol 1068*, when applied as dusts, were killing grasshoppers on the sixth and seventh days after application.—11-27-46.

[1] A Hercules Powder Co. product.
[2] *Velsicol 1068*.
[3] 1-Trichloro-2,2 bis (*p*-bromophenyl) ethane.
[4] Di (Methoxyphenyl) trichloroethane.

Gynandromorphism in Mosquitoes

MARGARET WARREN[1] and SAMUEL O. HILL,[2] *Seventh Army Medical Laboratory,*[3] *Fort McPherson, Ga.*

From approximately two million adult mosquitoes examined at the Seventh Army Medical Laboratory, Department of Entomology from 1942 to 1946 inclusive, gynandromorphism has been reported in four specimens. Middlekauff (1944) reported three specimens exhibiting gynandromorphic characteristics in *Culex pipiens-quinquefasciatus* and *Culex quinquefasciatus*. Rings (1946) reported the same in a single specimen of *Culec nigripalpus*. The reporting of the present specimen brings the total to five from this laboratory during the past five years. It is interesting to note that all the gynandromorphs reported from this laboratory were collected in September except one collected on August 15.

[1] SP-5 Entomology Department.
[2] Major, Sanitary Corps, AUS.
[3] Formerly designated Fourth Service Command Medical Laboratory.

The present specimen *Culex nigripalpus* Theobald was collected in a New Jersey type electric light trap at Fort Jackson, S. C., 23 September 1946, along with one male and two female normal specimens of the same species. Other normal specimens in the same collection were one male *Culex salinarus*, on female *Culex* (*Melanoconion*) species, three female *Aëdes atlanticus-tormentor* and one female *Uranotaenia lowii*.

This specimen possesses antennae and palpi which are typical female and the abdomen and genitalia exhibit typical male characteristics. The tarsi and some other leg segments are missing. The specimen has been deposited in the U. S. National Museum, Washington, D. C.—11-2-46

LITERATURE CITED

Middlekauff, Woodrow W. 1944. Gynandromorphism in Recently Collected Mosquitoes. JOUR. ECON. ENT. 37(2): 297.

Rings, Roy W. 1946. Gynandromorphism in *Culex nigripalpus*. JOUR. ECON. ENT. 39(3): 415.

ANNOUNCEMENTS

It is planned that in the future announcements of general interest to readers of the JOURNAL shall be published in this space immediately following the Scientific Notes.

The announcements will include matters concerning the business of the Association and its Branches and Sections, information issued by various committees, and the Bureau of Entomology and Plant Quarantine, especially those from the Committees on Common Names of Insects and the Terminology of Insecticides. Also from the U. S. National Museum giving information concerning changes in official technical names for insects of importance to economic entomologists, and JOURNAL announcements. Other items which members may from time to time deem to be suitable for this space will be accepted and used when possible.

New Policy on Charges for Reprints. Because the interests of persons who purchase reprints, especially where institutional orders are involved will be better served thereby, as well as for the sake of convenience to the JOURNAL, a new policy on reprint charges is being worked out. In this new schedule of prices, all prices will represent the established cost of the reprints, set by the printers, plus the transportation charges. In this way the purchasers can be informed in advance of the exact cost to them of the reprints and no separate item for transportation will appear on the bills. Details of the new schedule are not yet completed but will be announced in the April issue of the JOURNAL and will probably be in effect beginning with the June issue. It can be stated now that the cost to purchasers will in no case exceed that which they would incur under the existing schedule of prices. To avoid misleading anyone the old schedule is omitted from this issue of the JOURNAL.

RECORDING NAMES FOR TWO INSECTICIDES

The Commission of Patents has complied with the request of the Department of Agriculture and has recorded the following names for two insecticides:

"Chlordane" and "technical chlordane," recorded February 27, 1947, for the newly developed chlorinated hydrocarbon with the empirical formula $C_{10}H_6Cl_8$ and referred to under the trade names *Velsicol 1068* and *Octa-Klor*.

"EQ Smear 82," recorded March 13, 1947, for the formula used in the control of screwworm described in Bureau of Entomology Circular E-708.

Bureau of Entomology & Plant Quarantine
March 28, 1947

JOURNAL OF ECONOMIC ENTOMOLOGY
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Keeping up with the Literature

THE entomologist has numerous keys to literature but he needs better ones if he is to keep fully posted on what other workers have done and are doing in his field. Our Banks and Colcord Index has been of great help but is now years behind. An annual index in the same style has been proposed. There could be no better use of our Association's permanent funds than in compiling, editing, and publishing an annual Index to Entomology, not limiting it to American and economic writings.

Biological abstracts and the Review of Applied Entomology are excellent services which keep within six to twelve months of the current output. However, the indexes to these summaries are usually another six to twelve months in the making, delays that may be impossible to overcome.

There are several indexes to titles which are valuable. My favorite, from the standpoint of completeness, timeliness, and convenience, has been Wilson's Agricultural Index. As an example of the first two qualities this index has listed to date 21 papers on the comparatively new insecticide benzene hexachloride or gammexane. "Gammexane" is cross-indexed under "Insecticides." Wilson's Index has a three-year cumulative system dating back to 1916. The comparatively new Bibliography of Agriculture published by the U.S.D.A. is even more exhaustive. It has listed 61 papers on benzene hexachloride (including only 10 of those in Wilson's). The Bibliography of Agriculture sometimes gives very brief abstracts with the titles.

For the "uneconomic" worker there is "Current Entomological Literature" in *Entomological News*.

Incidentally these indexes suggest the need of using great care in selecting a title for one's paper so that it will be a true key to the contents.

Now for some thoughts on the improvement of the index to the JOURNAL OF ECONOMIC ENTOMOLOGY. A reader should be able to find what is in the JOURNAL without an outside reference. I believe that considerably more items should be taken from the body of each article when compiling the index and not rely on the title alone.

A study of Volume 38 (1945) shows about 650 entries in the index, less than one to the page and an average of 2.4 to the paper, including cross references to common and scientific names. Take a few obvious omissions. Page 23, "Experimental use of gas condensate for the prevention of fly breeding." The index has one entry, "Gas condensate against flies." The work is entirely on the stablefly, the paper should have been indexed under this species. Page 35, "Soil treatments with reference to fumigation with DD mixture." This is indexed under "Soil," "Fumigation," and "DD," but there is no reference to the crop treated, pineapple. Page 119, two papers on *Macrocentrus ancylivorus* in both of which the strawberry leaf-roller is a major consideration. There is no index reference to the latter insect. Page 125, "Preliminary tests with sabadilla." The index refers to "Sabadilla" but to none of the five species of insects which were used in the tests.

As an example of how these omissions accumulate over a period of time, here is my experience on gathering information on peanut insects. In the period 1937 to 1945 the JOURNAL carried at least 14 papers dealing with this group but only four were indexed under "peanuts." In two others, "peanut" was in the title; in four it was a major consideration, sometimes noted in a subhead; in the remaining four peanut was a minor consideration.

The answer has been given that there is danger of overindexing a paper with items that will rarely be used. Would it not be better to err on the side of overindexing than to leave out items that a worker may sometime want? Three or four more pages of index in each volume would be of considerable service. Several people, of different entomological interests should work on each index to better satisfy varied needs.

These suggestions are made toward the end that published results be more readily used and that entomologists be aided in keeping up with their science.

THEODORE L. BISSELL

Joseph Henry Merrill (1881–1946)

Dr. Joseph Henry Merrill, a life member of the Association, died on November 21, 1946, at his home in Raynham Center, Massachusetts. Dr. Merrill was born at Danvers, Mass., on November 12, 1881. He received his bachelor's degree from Dartmouth College in 1905 and his doctor's degree from Massachusetts State College at Amherst in 1914.

Dr. Merrill was employed in gypsy moth suppression work in Danvers from 1905 to 1909 and was a deputy State Nursery Inspector in 1910 and 1911, with headquarters at Amherst, where he also was Lecturer in plant pathology. In 1912 he went to Kansas State Agricultural College as Associate Professor of Apiculture in the College and Experiment Station Apiculturist and remained there until 1925 when his physical condition necessitated his retirement. From 1918 to 1925 he was State Apiculturist of Kansas.

From the time of his retirement he was physically incapacitated by a paralytic condition but this had no effect on his mental capacity and his innate fortitude made it possible for him to continue his interest in his major field of apiculture and to broaden his interests in many directions. He was able to continue certain types of research and published many articles, mainly in magazines devoted to bee-keeping, until as late as 1941.

His home became a center of attraction for beekeepers and entomologists who were within reach, as residents or visitors, and he was enabled to keep in touch with current trends through visitors; but always, he gave as much, in inspiration and genuine social pleasure, as he received.

On September 12, 1912, he was married to Lillian Briggs who, with their two children, Joseph Briggs and Frances Somerville, survives him.

Dr. Merrill was a fellow of the Apis Club, 1926, and a member of Phi Gamma Delta, Phi Kappa Phi and Gamma Sigma Delta.

A victim of circumstances which would have embittered the most optimistic, Dr. Merrill was able to rise, to a remarkable degree, above his misfortune and to live a full and useful life in spite of it.

Dr. Clement Samuel Brimley

Dr. C. S. Brimley, best known for his Insects of North Carolina, died in Raleigh, North Carolina on July 23, 1946. He was born in Great Linford, England on December 18, 1863. Dr. Brimley came to this country in 1880 and settled near Raleigh. In 1881 he and his brother, H. H. Brimley, organized a firm for collecting natural history specimens. Later his brother became curator of the North Carolina State Museum. Dr. Brimley joined the Division of Entomology and continued active in this position until his death. In this position he brought to bear his wide interest in animals of all groups and organized a detailed catalog of the animals of North Carolina. He contributed substantially to our knowledge not only of the insects of the state but also to the fishes, amphibians, reptiles, birds, and mammals of North Carolina. Thus the world has witnessed the passing of another great naturalist.

Z. P. METCALF

ENTOMOLOGICAL SOCIETY OF PENNSYLVANIA MEETS IN HARRISBURG

The Twenty-first Annual Meeting of the Entomological Society of Pennsylvania met in Room 107, South Office Building, Harrisburg, Pennsylvania, on January 15, 1947, at 4:30 P.M.

Those in attendance were:

G. B. Stichter, Philadelphia
J. M. Corliss, Wilkes Barre
A. J. Pruett, Wilkes Barre
W. H. Hanley, Wilkes Barre
C. F. Campbell, Wilkes Barre
L. L. Peirce, Wilkes Barre
Dr. T. L. Guyton, Harrisburg
W. C. Wheatfield, Harrisburg
A. B. Champlain, Harrisburg
E. M. Craighead, Harrisburg
G. B. Sleesman, Norristown
H. A. Strohecker, Norristown
M. W. Eddy, Dickinson College, Carlisle
J. O. Pepper, State College
S. G. Gesell, State College
E. J. Udine, State College,
H. Menusan, State College
Harold Steiner, Flora Dale

The meeting was called to order by Chairman C. F. Campbell. The minutes of the last meeting of the Society, held in 1943, were read by G. B. Sleesman, Secretary. The nominating committee offered Harold Steiner for Chairman, G. B. Sleesman for Vice-Chairman and E. J. Udine for Secretary. Chairman Campbell then instructed the secretary to cast ballot for these officers.

Chairman Campbell called upon G. B. Stichter to give a short outline of the history of the society since its beginning. His talk was very interesting and he stated that the membership should be larger than its present membership and suggested that men in private industry be contacted and get them on the active membership list.

A round table discussion then followed and much interest was taken by men in attendance of the work being done in the laboratory and in the field. Dr. Eddy gave a short talk on his work at the college. Mr. Craighead reported on the potato rot Nematode. Dr. Champlain reported on the nursery inspection work in the state. He also reported on unusual insect pests in the nurseries. Mr. Wheatfield reported on cooperation of nurserymen with the inspection service. Dr. T. L. Guyton reported on apiary inspection, due to the absence of H. B. Kirk. Mr. Hanley, Mr. Pruett and Mr. Corliss reported on the work being done towards the control of the Gypsy Moth in the Wilkes Barre area. Mr. J. O. Pepper, Mr. Gesell, Mr. Udine and Mr. Menusan gave interesting reports on new inseciticides; what to expect and what not to expect of these new insecticides until more was known about them. Chairman Campbell gave a short report on the Gypsy Moth Control. Mr. Sleesman reported on the scale insect identification work being carried on in addition to regular work.

Mr. J. O. Pepper then suggested that there should be more men carrying on taxinomic work on the insects found in Pennsylvania.

The meeting adjourned at 7:30 P.M.

G. B. SLEESMAN, *Secretary*

CONFERENCE OF ARMY ENTOMOLOGISTS

Entomologists employed by the War Department for the supervision and execution of insect and rodent control at military installations participated in a conference at the Office of the Chief of Engineers, Washington, D. C., January 27, 28, and 29, 1947. The following entomologists were in attendance from the Insect and Rodent Control Sections of the various Engineer Headquarters for Repairs and Utilities:

W. D. Reed, Office of the Chief of Engineers, Washington, D. C.
R. W. Bunn, Office of the Chief of Engineers, Washington, D. C.
H. H. Laidlaw, Jr., Headquarters, First Army, Governors Island, N. Y.
S. S. Easter, Headquarters, Second Army, Baltimore, Md.
K. S. Littig, Headquarters, Seventh Army, Atlanta, Ga.
Theodore McGregor, Headquarters, Fourth Army, Fort Sam Houston, Tex.
V. I. Miles, Headquarters, Fifth Army, Chicago, Ill.
M. F. Bowen, Headquarters, Sixth Army, San Francisco, Calif.
J. H. Robinson, Headquarters, Air Training Command, Barksdale Field, La.
G. L. Hutton, Headquarters, Tactical Air Command, Langley Field, Va.
C. B. Wisecup, Headquarters, Air Transport Command, Gravelly Point, Va.
A. W. Morrill, Jr., Headquarters, Philippines—Ryukyus Command, Manila, P. I.

Others in attendance at the conference included Major F. S. Blanton, Office of the Surgeon General, Doctor T. E. Snyder, R. A. St. George, and E. F. Knipling, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, W. Leh, Headquarters, Army Air Forces, H. J. Spencer, Fish and Wildlife Service, U. S. Department of the Interior, and Commander J. D. De Coursey, U. S. Navy.

Topics discussed on the program included War Department policies and procedures for insect and rodent control; aerial dispersal of insecticides; insecticides and rodenticides recommended for use by the Army; and supplies and equipment for the performance of insect and rodent control work.

A visit was made to the Research Laboratories of the Bureau of Entomology and Plant Quarantine, Beltsville, Maryland, on January 28 to review the current program of research in economic entomology.

TWENTY-FIRST ANNUAL WESTERN COOPERATIVE SPRAY CONFERENCE

The Twenty-first Annual Conference of the Western Cooperative Spray Project was held at Portland, Oreg., on January 22 and 23. The experiment stations of California, Idaho, Montana, Oregon and Washington, the Bureau of Plant and Insect Control of the Colorado Division of Agriculture, the Canadian Department of Agriculture, and the U. S. Department of Agriculture comprise the members organizations of this official project, which is engaged in research work on orchard spraying problems in the West.

Discussion was particularly centered about the control of orchard mites, which has become a major problem with the advent of DDT. Research work on the codling moth, scale insects, aphids, cherry fruit fly, filbert insects, pear thrips, cranberry insects, peach insects, pear scab and diseases of stone fruits was also covered. Reports were given on the status of the pear psylla and the Oriental fruit moth in the West.

As a by-product of these discussions, the usual suggestions for the use of orchard sprays were brought up to date, and these included mention of DDT and a warning of the dangers of its use in orchards. These suggestions are used by experiment stations and others in the area as a basis for making recommendations.

At noon of the second day the conference adjourned for a group luncheon with representatives of insecticide manufacturers and distributors, field men of growers' organizations, horticultural inspectors and others. A joint meeting was then held, presided over by Ed Littooy, of the Colloidal Products Corporation, at which the above mentioned suggestions were discussed and information was given on the availability of insecticides and fungicides. The attendance at the joint meeting was about 250, which is much larger than ever before.

The attendance at the closed meetings was also unusually large, about 60 members and visitors being present. Individual members attending included entomologists, chemists, plant pathologists, and horticulturists, and they were as follows:

CANADIAN DEPT. OF AGRICULTURE
Harry Andison — Ben Hoy
C. V. G. Morgan

CALIFORNIA
M. P. Barnes — C. E. Scott
G. L. Smith

IDAHO
A. S. Horn — H. C. Manis

OREGON

Leroy Childs	C. H. Martin
A. W. Evans	H. E. Morrison
R. W. Every	R. H. Robinson
L. G. Gentner	R. G. Rosennstiel
S. C. Jones	B. G. Thompson
	S. M. Zeller

WASHINGTON

D. F. Allmendinger	Folke Johnson
E. C. Blodgett	T. A. Merrill
D. H. Brannon	W. J. O'Neill
E. P. Breakey	F. L. Overley
L. R. Bryant	J. C. Snyder
A. M. Bullock	L. L. Stitt
D. J. Crowley	J. L. St. John
P. M. Eide	K. C. Walker
G. W. Fischer	R. L. Webster

U.S.D.A.

F. P. Dean	J. R. Kienholz
S. M. Dohanian	E. J. Newcomer
K. A. Haines	W. E. Westlake

E. J. NEWCOMER, Yakima, Wash., *Chairman*
F. L. OVERLEY, Wenatchee, Wash., *Secretary*

COTTON STATES BRANCH
AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS
Proceedings of the Twentieth Annual Meeting
Dallas, Texas, December 3–6, 1945

The twentieth annual meeting of The Cotton States Branch of the American Association of Economic Entomologists was held in conjunction with the annual meeting of the parent association in Dallas, Texas, on December 3, 4, 5, 6, 1945. The Cotton States Branch and The Texas Entomological Society served as official hosts for these important meetings. The officers and members of these two regional organizations rendered great service to the National Organization in planning the sessions, and making all necessary arrangements. Doctor E. W. Laake and the committee on local arrangements rendered excellent services.

Doctor C. E. Smith, Chairman of The Cotton States Branch, was provided a prominent program position for the presentation of his address, entitled, "Comments on Post War Entomological Problems in the South." This was a well prepared and presented paper and brought many favorable comments from those in attendance.

A special feature of the Branch activities during the meetings was a luncheon for members of the post war planning committee for Southern Entomology. Several prominent guests were in attendance. Dr. F. L. Thomas, chairman of the committee, presided. The discussions were stimulating to all present.

BUSINESS PROCEEDINGS

The special business session for the Cotton States Branch was well attended by members.

The Secretary-Treasurer presented the following report:

Funds Received		
Jan. 17, 1945	Amount on hand in savings	$ 122.90
Jan. 17, 1945	Amount in checking account, University of Florida	131.76
July 1, 1945	Interest on deposit in savings department of First National Bank, Atlanta, Georgia, from Jan. 1, 1945 to July 1, 1945	.60
Feb. 1, 1945 to Dec. 1, 1945	Contributions from members of Industry to cover cost of stenotypist and lithograph off-set printing of proceedings.	489.70
July 23, 1945	Received from Ernest N. Cory, Secretary-Business Manager of The American Association of Economic Entomologists. Refunds for specified Branch expenses.	102.93
Jan. 17, 1945 to Dec. 1, 1945	Dues and registration fees	164.00
	Total funds received	$1011.89
Expenditures	Miscellaneous items	653.07
Balance on Hand, December 1, 1945		$ 358.82

REPORT OF THE NOMINATING COMMITTEE

The Nominations Committee recommended the following officers:

R. C. GAINES, Tallulah, Louisiana, Chairman
J. A. BERLY, Clemson College, S. C., Vice-Chairman

The term of office of the Secretary-Treasurer does not expire until 1948.

These officers were duly elected and installed.

JOHN T. CREIGHTON
Secretary-Treasurer

NORTH CENTRAL STATES BRANCH
AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS
Proceedings of the First Annual Meeting
St. Louis, Missouri, March 27, 28 and 29, 1946

The first annual meeting of the North Central States Branch of the American Association of Economic Entomologists was held in St. Louis, Missouri, on March 27, 28 and 29, 1946. The meeting was a joint session with the Entomological Society of America, in conjunction with the annual A.A.A.S. meeting.

Entomologists of the North Central States have met in annual session for many years, but it was not until the 1945 meeting at Purdue University that action was taken to request Branch membership in the A.A.E.E. The first duly elected officers in this new branch were: J. J. Davis, President, and M. D. Farrar, Secretary-Treasurer.

The past policy of this group to conduct its meetings on an informal discussion basis was maintained during the St. Louis meetings. Sectional meetings dealing with insect problems of the region occupied the greater portion of the program. One sectional meeting on ground equipment and a special symposium on aerial distribution of insecticides proved of great interest to those in attendance.

Some 200 persons registered during this year's meeting. Conditions for full and associate membership in this Branch were established at St. Louis with the approval of the Constitution and By Laws. Active membership now stands at 46 and associate membership at 36.

Prior to full Branch status, this organization maintained no funds for future operations. At the time of the first annual meeting there was only $10 to the credit of the organization. This amount was the surplus remaining after paying the cost of preparing and mailing the mimeographed 1945 proceedings.

Officers elected for the year 1946–47 were: J. S. Houser, President; H. H. Harris, Vice-President; and M. D. Farrar, Secretary-Treasurer. Three months after the annual meeting, M. D. Farrar accepted a position on the east coast and resigned his office. Pres. Houser requested J. W. Apple to take on the duties of Secretary-Treasurer for the remainder of the year.

The organization accepted the invitation of the Iowa delegation to hold the Second Annual Meeting at the Hotel Fort Des Moines, Des Moines, Iowa, from March 26 to 28, 1947.

JAMES W. APPLE, *Acting Secretary-Treasurer*

PROCEEDINGS OF THE FIFTY-EIGHTH ANNUAL MEETING

American Association of Economic Entomologists

Hotel John Marshall, Richmond, Virginia, December 9 to 12, 1946

The fifty-eighth annual meeting of this Association was scheduled for the Hotel William Penn, Pittsburgh, Pennsylvania; but due to the hotel strike there, it was necessary to change the place of meeting to the Hotel John Marshall, Richmond, Virginia, without change of date. Elaborate preparations by the Pittsburgh Local Committee headed by A. C. Miller had been made, especially for the entertainment of the guests at the banquet. All of these preparations had to be cancelled and in-so-far as possible the entire list of hotel reservations transferred to Richmond. The management and operating staff of the Hotel John Marshall cooperated wholeheartedly and so effectively that practically all of the people who had made reservations at Richmond were able to be accommodated at the John Marshall. Those who could not be so accommodated were taken care of in nearby hotels.

Instead of decreasing the attendance, the change to Richmond proved to be a very fortunate one in that probably the largest registration ever recorded for the combined societies developed at this meeting. The actual registration was 393.

All of the branches and sections held sessions including the new section on insecticides which began their meeting with a dinner with over 100 in attendance. The meeting following the dinner had an attendance of over 200 and wound up with the showing of motion pictures of two new type fog distributors.

Subjects of general interest were presented each morning throughout the four day session. The Presidential Address, "Achievements and Possibilities in Pest Eradication" by President Clay Lyle; "An Entomological Survey of the Micronesian Islands" by H. K. Townes and R. G. Oakley and a symposium on Insect Physiological Research in Relation to DDT and Other New Insecticides led by J. F. Yeager occupied the first two mornings. An interesting presentation of the aims of the United Nations Educational, Scientific and Cultural Organization was made by Dr. Detlev W. Bronk on Wednesday morning. This address was followed by Preventative Entomology by P. N. Annand and the Proposed Revision of the Federal Insecticide Act and the Need for Uniform State Legislation by W. G. Reed. The final morning session consisted of another symposium following the business meeting. This was on Equipment and Methods of Application of Insecticides led by A. M. Boyce.

Outstanding on the program of the Entomological Society of America was the annual public address on Early Insect Life by Dr. Frank M. Carpenter of Harvard University which was delivered on Monday evening to a large and attentive audience.

Business Transacted at the Final Business Session

Considerable business was transacted in the two business sessions held during ths meeting. Both sessions were remarkably well attended and the actual items will appear elsewhere in the reports of the committees and in the results of several votes. Probably the item of greatest general interest was the passage of the amendment changing the method of nominating the President and First Vice President.

Part of the reports of standing committees were presented on the first day and those which were not reached on that day were carried over to the final business session. All of these reports will be found elsewhere in their entirety. Action on the report of the Committee on Popular Entomological Education will be found in the detailed report of the Final Business Session and the complete report is printed with the other reports of standing committees.

Report of the Secretary-Treasurer

On August 23, 1946, I sent a letter to the members of the Executive Committee, parts of which are here quoted with a clarifying statement in the second paragraph indicated by parentheses.

"The work of the Office of the Secretary and Business Manager has increased since the present incumbent took office to such an extent that he has been giving serious thought to how that burden can be handled most efficiently and economically. In 1937 the membership totalled 1,024. In 1946, after nine years, the total has reached 1,880, or nearly doubled. The subscription list, despite war's interruptions has increased from approximately 1,500 to 2,817 and is constantly growing.

"The business of the Association has been handled (by the several secretaries) as a 'Labor of love' from the beginning (this was especially true of the service of Mr. Burgess). Only since the present incumbent began his work has there been provision for clerical assistance which, up to recently, has been adequate. Every Executive Committee has looked with favor upon providing sufficient funds to carry on the operations but quite naturally has not gone beyond the recommendations of the Secretary, although the late President Strong wanted to increase the Secretaries' stipend and provide greater clerical funds for both the Editor and the Secretary.

"Many discussions in Committee meetings and in the hotel lobbies about a full time Secretary have come to naught because of lack of sufficient funds. The income from the Permanent Fund is only about $750.00 to $800.00 annually so that the current funds would have to be drawn upon. Actually to get the kind of full time secretarial help that would insure progress in the Association and efficient management of the Journal would require a salary of $5,000, as a minimum, clerical help of about $3,000 including extra clerical labor and $2,000 for office space, facilities, etc., or a total of $10,000 per year. Any less salary to the Secretary would necessitate that individual having some independent income or else he would find it necessary to supplement his income in some way. In the latter event, the Association would be back in the category of employing part time help.

"At the present, Association business occupies a

large proportion of my time and that of my Secretary who is paid $480.00 per year by the Association. She and I work every other Saturday, holidays and many nights on the actual routine of bookkeeping, letter writing, posting cards, entering changes of addresses, ordering subscriptions and back numbers. With all of this effort, the business of the Association is not performed adequately. What is really needed is to have a stenographer-bookkeeper employed full time at a salary that will assure, within reason, continuity of management. Continuity is essential because the business is complicated, cannot be learned quickly and much of it depends upon a knowledge of the personality of the membership. If a full time stenographer-bookkeeper should be employed, the delays that irritate members would be largely eliminated and the business would be more stable, efficient and more economical than by the employment of a full time Secretary and Business Manager who would have to employ stenographic and bookkeeping help in any event. A full-time stenographer should receive approximately $2,500 which means an increase over present clerical costs of about $1,900 to $2,000. If I can secure another secretary to handle the University and State business, I should like to see Miss Hermann made a full time stenographer-bookkeeper for the Association as I am confident that she would so increase the efficiency of the handling of the Association business that it would be possible to increase the volume of sales of subscriptions and advertising and to render more service to the membership. If this change is effected, it will eliminate considerable of the detail work and overtime of the present Secretary."

On August 31, my secretary had two offers of $2,750 to transfer to one of two Dean's offices as Secretary-Stenographer and I telephoned Van Dine and Hoyt for advice. The loss of her services to the Association, particularly at this time, would have been a calamity. A new Department secretary would have had no time to do any effective Association work. I found that Miss Hermann would be willing to take full-time employment with the Association in preference to transferring to another office on the campus. Dr. Van Dine suggested that she be offered a sufficient amount to make other campus offers less attractive. A canvass of the Executive Committee by telegram and telephone showed eight members in favor of employing Miss Hermann at $3,000 per annum and one opposed, not to the principle, but to the amount of salary. Since this was an emergency, the Executive Committee authorized the full time employment of Miss Hermann, but desires a confirmation of its judgment. A motion covering this item will be included in the recommendations of the Executive Committee to be presented Thursday morning.

At this writing, the routine work of the Association is on a full time basis. The volume has surprised even your Secretary, but of course this is written at the time when dues are coming in in considerable volume daily and address changes are numerous. For the first time since the present incumbent took over, the work is handled on a current basis. I believe this is the best solution of our problem that could be found and wonder how it was possible in the past even to approximate efficient conduct of the Association business.

An important decision must be made with regard to the policy relative to the time and place of meeting. Many teachers find it difficult or impossible to meet before Christmas. Many members want to meet with the AAAS. This is particularly so among the members of the Entomological Society of America and if we are to continue the very desirable joint meetings, we must take cognizance of this desire. On the other hand, we must serve all our membership by holding meetings in the several regions in order that everyone may participate in meetings reasonably near to their homes.

Picking out cities in the areas far removed from the geographical center of our population that should be given consideration as meeting places we find the following lapses of years since the last meeting there: Denver—45, Minneapolis—36, Atlanta—34, Canada (Toronto)—25, Kansas City—20, Des Moines—17, New Orleans—15 and Boston—13. Of all these places, Boston only is in the area in which the AAAS policy permits winter meetings as the announced policy of the AAAS is to meet in four areas, east of the Mississippi and north of the southern border of Virginia. Such other cities as Ottawa, Montreal, Toronto, Quebec, Jacksonville, San Antonio, Memphis, Nashville, Omaha, Salt Lake City, Seattle and Los Angeles are also beyond the pale but represent areas where many entomologists work. A meeting in any of these cities would be worthwhile and serve members that deserve our consideration. How to reconcile these divergent desires and needs presents a problem in compromise. If the AAAS would set up a long term schedule, we could fit into the scheme possibly every other or every third year, but there is no certainty even that next year's meeting will be held in Chicago and the 1948 meeting place is tentatively set for New York City. Pittsburgh (or Richmond) is the east to many members so it would be somewhat unfair to return to New York for 1948. Although on the other hand that would give two sessions with the AAAS. Probably our best arrangement would be to set up a new 5 or 10 year plan starting with Chicago in 1947 and hope that war or strikes will not necessitate cancellations or changes.

As I see it the best move would be to definitely return to the post-Christmas date. This would enable teachers to attend and would permit scheduling our meetings with the AAAS at least part of the time. The other step would be to outline a long term schedule and the following is offered for your consideration:

1947—Chicago with the AAAS
1948—New York with the AAAS
1949—In the South (Jacksonville, Atlanta, New Orleans)
1950—In the West (Kansas City, Denver, Omaha, Des Moines, Salt Lake City)
1951—In the Mid-West (hoping that the AAAS will meet in this area and being governed by their choice of city—possibly Columbus, Cleveland, Cincinnati or Indianapolis)
1952—In the East, again hoping that the AAAS will meet in the East. (If the AAAS decides on the East in 1951 and the Mid-West in 1952, we should reverse this schedule for 1951 and 1952.)
1953—West Coast—Los Angeles, San Francisco, Seattle
1954—In the North (possibly a Canadian city, Boston or Buffalo). (There is of course the possibility that the AAAS will be meeting in this area.)
1955—In the Southwest (San Antonio, Houston, Dallas, Ft. Worth)

This schedule is flexible as to exact place, provides for at least four meetings with the AAAS, coincides with their meeting time and provides that every area in the U. S. may be adequately served. If circumstances that develop determine that it is unwise to go south in 1949, it would be possible and practical to interchange the 1949 and 1950 schedule. This also gives local groups a chance to plan a long time ahead in order to make their meeting a success. For instance, the west coast entomologists can determine in which city they want to hold the meeting and then prepare long in advance to make a success of their meeting.

The work on the Index is progressing. At the suggestion of Mr. Ralph R. Shaw, a photostating process is being employed to reproduce the cards in place of typing the data in manuscript form. Shortage of typists in the B.E.P.Q. made the typing impossible. Under the photostat process which has been approved by the printer, it is hoped that the photo manuscript after being checked by Dr. Muesebeck's office will be available to the Editor, Dr. Stanley W. Bromley, before too long. Shortages of paper and manpower in the printing plant would have precluded publication before this, even had the manuscript been ready so we probably are just as far along with the project as possible.

In accord with the vote on the gift to the AAAS, a check for $2,000.00 was sent on July 3, 1946 and duly and appreciatively acknowledged by letter and in the *Bulletin* of the AAAS. The newly purchased place on Massachusetts Avenue in Washington is now occupied by the AAAS. Out of 1880 ballots sent out, only 733 were returned. Possibly we have been unduly perturbed by the small number participating in the business sessions. Maybe most members are willing to let a few vote and manage the business leaving them in their "ivory tower."

However, there is to come up at the final business meeting a vote on a change in the Constitution relative to the method of electing the President and First Vice-President. This is in response to the feeling of some that we have not been democratic enough (see above total ballot). Personally I consider the move unnecessary and feel that the Nominating Committee method adequate and safe, but even though this new method entails considerably more work, we are now prepared to handle that work on time and if the method turns out to be labored and possibly unworkable, we can always make a change.

You will probably hear from the Editor or the Publication Committee in regard to the paucity of manuscripts. Actually the JOURNAL is yours and manuscripts should be sent to it rather than to other publications which are more in the nature of Trade Journals. The present year has been the most difficult the printer has experienced. Delays have been inevitable, but the situation is clearing and it is quite probable that you will get quicker action in your own JOURNAL next year and subsequently than in any other media.

The membership will receive without cost a reprint of the list of Common Names of Insects. Copies may be purchased for 50¢ each.

The Membership Committee will report in detail the deaths totaling 12 and resignations totalling 14. Eighteen were dropped either because of non-payment or because mail has been returned over a period of months.

ERNEST N. CORY, *Secretary-Treasurer*

December 7, 1946

Dr. Ernest N. Cory, Secretary-Treasurer
American Association of Economic Entomologists
College Park, Maryland

Dear Dr. Cory:

I have examined the statements of receipts and disbursements of the General Fund, Permanent Fund and Special Journal Fund of the American Association of Economic Entomologists for the fiscal period November 21, 1945 to November 30, 1946, have reviewed the accounting procedures of the Association, and without making a detailed audit of the transactions, have examined or tested accounting records of the Association, and other supporting evidence, by methods and to the extent deemed appropriate. My examination was made in accordance with generally accepted auditing standards applicable in the circumstances and included all procedures which I considered necessary.

In my opinion, the accompanying statements of receipts and disbursements of the General Fund, Permanent Fund and Special Journal Fund fairly present the recorded cash transactions of the Association during the fiscal period and its cash and securities position at November 30, 1946.

Yours very truly,
PAUL E. PYLES
Certified Public Accountant

AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

GENERAL FUND

STATEMENTS OF RECEIPTS AND DISBURSEMENTS

FOR THE FISCAL PERIOD NOVEMBER 21, 1945 TO NOVEMBER 30, 1946 INCLUSIVE

	TOTAL	JOURNAL	ASSOCIATION	INDICES I–V	INDEX VI	INDEX VII	INDEX VIII
Receipts:							
Subscriptions	$ 9,073.65	$ 9,073.65					
Advertising	157.11	157.11					
Reprints	821.07	821.07					
Back numbers and miscellaneous	377.14	377.14					
Dues	3,805.00		$2,853.75			$ 475.75	$475.50
Sale of indices	218.00			$164.00	$ 54.00		
Registration—Reemployment and Placement Committee	56.00		56.00				
Interest on bonds	50.00		50.00				
Total receipts	$14,557.97	$10,428.97	$2,959.75	$164.00	$ 54.00	$ 475.75	$475.50

Disbursements:							
Printing	$ 9,464.69	$ 9,464.79					
Engravings	435.09	435.09					
Honorarium—Editor (1944–1946)	600.00	600.00					
Honorarium—Business Manager and Secretary-Treasurer	600.00	300.00	$ 300.00				
Editorial expenses	398.58	398.58					
Stenographic and clerical salaries and wages (Note)	691.81	377.81	377.82			$ 16.18	
Traveling expenses	549.48		549.48				
Branch expenses							
Cotton States	59.18		59.18				
Pacific Slope (1944–1946)	203.55		203.55				
Postage, stationery and supplies	342.08	171.04	171.04				
Telephone and telegraph	60.52		60.52				
Accounting and auditing fees	60.00	30.00	30.00				
Surety bond for Secretary	12.50	6.25	6.25				
Express	19.68		19.68				
Bank service charges	37.19	18.60	18.59				
Safe deposit box rental	3.60		3.60				
Dallas meeting expenses—projection, badges and programs	102.98		102.98				
Total disbursements	$13,641.03	$11,762.16	$1,862.69	—	—	$ 16.18	—
Excess of receipts over disbursements	$ 916.94	$ 1,333.19*	$1,097.06	$164.00	$ 54.00	$ 459.57	$475.50
Add: Balance November 20, 1945 per previous report	5,717.74	702.77	4,997.41	497.41	2,752.00*	1,928.59	343.55
Adjustment relating to prior periods	104.50	52.25	52.25				
Balance November 30, 1946	$ 6,739.18	$ 578.17*	$6,146.72	$661.41	$2,698.00*	$2,388.16	$819.06
Balance consists of:							
Cash in Prince George's Bank & Trust Co. (checking account) and on hand	$ 4,839.18						
U. S. Savings Bonds, Series G, 2½%, at cost	2,000.00						
	$ 6,839.18						
Less: Amount due Permanent Fund	100.00						
	$ 6,739.18						

* Indicates deficit.
Note: Excludes $35.50 Federal income tax withheld.

PERMANENT FUND

Balance, November 21, 1945		$27,353.67
Receipts:		
Interest on securities	$298.75	
($62.50 additional due November 1, 1946 on U. S. bonds, Series G, but not received)		
Interest on savings deposit	70.72	
Increment to redemption value of U. S. Savings Bonds, Series D (added to book value)	300.00	
Donation	2.00	
		671.47
		$28,025.14
Expenditures:		
Grant to American Association for the Advancement of Science		2,000.00
Balance, November 30, 1946		$26,025.14

Balance consists of:
Securities

Face Amount		Book Value
$ 2,000	Province of Ontario 5% Debenture Bonds due May 1, 1949, at cost	$2,000.00
3,000	U. S. Treasury 2½% Bonds of 1955–1960, at cost	2,984.00
10,000	U. S. Savings Bonds, Series D, due Feb. 1, 1949, at redemption value	9,000.00
7,000	U. S. Savings Bonds, Series G, 2½%, at cost	7,000.00
		$20,984.00
Cash in Prince George's Bank & Trust Co. (savings account)		4,941.14
Due from General Fund		100.00
		$26,025.14

SPECIAL JOURNAL FUND

Balance, November 21, 1945	$500.00
Receipts:	
Interest on savings account	7.50
Disbursements:	
None	—
Balance, November 30, 1946, consisting of cash in Prince George's Bank & Trust Co. (savings account)	$507.50

REPORT OF THE FINAL BUSINESS SESSION

The Executive Committee recommended and the Association adopted or approved the following items: (1) An increase of $1.00 per year to the non-member subscription to the JOURNAL, (2) The tentative schedule herewith included and the motion relating to the time and place of meeting. (This likewise was considered and approved in principle by the Entomological Society of America), (3) That on the approval of the Executive Committee individual members who have been in good standing and who have retired from active service may be continued as active members with the remission of dues, (4) The termination of the special committee on Pan American cooperation, (5) In response to a request from the Agricultural Insecticide and Fungicide Association, the Executive Committee instructed President Lyle to appoint two representatives to the Committee with like representation from the American Phytopathological Association and the A.I. and F.A. to suggest policies concerning dealer education. Subsequently Dr. Lyle appointed George C. Decker and Charles E. Palm., (6) That its emergency action in employing a stenographer-bookkeeper in the Secretary's office at $3,000 annually be approved and made permanent, (7) By past action of the Association, $1,000 annually has been allocated for clerical expenses in the Editor's office. Due to circumstances beyond the Editor's control, it has been impossible for him to get the type of help necessary, resulting in the Editor's doing the work himself at a loss in his regular income. Therefore, the Executive Committee recommends that $400 from this item be added annually to the Editor's honorarium of $200, (8) That the report of the Committee on Popular Entomological Education be held for further study by the Executive Committee in view of the recommendations involving policies and finances, (9) That there be no change in the status of *Entoma*, (10) The following amendment to the Constitution is presented for consideration, subject to final action at the next annual meeting of the Association. "Article 3, Section 2, shall be amended to read as follows: All persons engaged in work in entomology or allied fields and other persons having suitable training or a deep interest in entomology may become active members upon consideration by and unanimous approval of the Membership Committee, after a regularly executed application, endorsed by two active members and accompanied by the required fee, has been filed with the Secretary-Treasurer.", (11) The following action be taken on the three separate items of the petition submitted by J. W. Enke in behalf of approximately 80 signers (a) Since the Association by approval of the Secretary's report in 1945 is on record of favoring the publication of the History of Entomology in the War Effort, the Executive Committee has instructed President Lyle to appoint two members who with a like number from the Entomological Society of America shall constitute a joint committee instructed to outline the content of such a history, to study the procedures necessary to develop that outline to recommend the type, place and financing of the publication and to recommend an editor. (b) That the second portion of the petition in regard to liaison be denied on the ground that the National Research Council on which this Association has representation is in a better position to function as a liaison of scientific endeavor with the Armed Forces and Public Health Agencies than any Committee of this Association. Moreover, there is a Committee on Insect Control of the National Research Council on which two entomologists are members and it should be assumed that it will function on lines indicated in the petition, (c) Medical Entomology—This item is not within the scope of the functions or responsibilities of the American Association of Economic Entomologists.

NEW BUSINESS

It was moved by Mr. Joseph W. Enke that a committee be appointed by the out-going or incoming President of the American Association of Economic Entomologists to study and report how best to encourage the development of Medical Entomology within this Association. When this was seconded, Mr. Enke made the following statement: "At present there is no nucleus within this Association about which the great current and potential interest in Medical Entomology may develop. If desired, this study may work in conjunction with a similar study committee just appointed by the Entomological Society of America." The motion was carried. Subsequently, President Lyle appointed E. F. Knipling and R. W. Bunn on the joint committee on the History of Entomology in the War Effort.

It was moved and seconded that the tentative schedule of annual meetings be adopted as a guiding principle and that the Executive Committee in office immediately prior to any meeting be authorized to determine the meeting city and dates in accord with this plan with special intent to meet the time and shifts of the American Association for the Advancement of Science so that there will be as many meetings with them as possible with justice to our membership that is remote from their areas of meetings. Further: That the Executive Committee be authorized to interchange meetings in one area with another area if and when circumstances dictate the desirability of such an exchange.

LONG TERM SCHEDULE

1947—Chicago with the AAAS
1948—New York with the AAAS
1949—In the South (Jacksonville, Atlanta, New Orleans)
1950—In the West (Kansas City, Denver, Omaha, Des Moines, Salt Lake City)
1951—In the Mid-West (hoping that the AAAS will meet in this area and being governed by their choice of city—possibly Columbus, Cleveland, Cincinnati or Indianapolis)
1952—In the East, again hoping that the AAAS will meet in the East. (If the AAS decides on the East in 1951 and the Mid-West in 1952, we should reverse this schedule for 1951 and 1952.)
1953—West Coast—Los Angeles, San Francisco, Seattle
1954—In the North (possibly a Canadian city, Boston or Buffalo). (There is of course a possibility that the AAAS will be meeting in this area.)
1955—In the Southwest (San Antonio, Houston, Dallas, Ft. Worth)

REPORT OF THE SECTION OF APICULTURE

The Section of Apiculture met at 1:30 o'clock Tuesday, December 10 in Parlor A, Hotel John Marshall, Richmond, Virginia.

On account of a conflict with a scheduled trip to Panama, the Chairman, Dr. F. L. Thomas was unable to be present. The Secretary called the meeting to order and requested nominations for a presiding officer. Mr. George J. Abrams, University of Maryland, was elected temporary chairman.

Of the nine titles on the program, seven were presented. Much interesting discussion developed around each topic, but special consideration was given to (1) bee sting therapy and (2) sulfathiazole treatment for American Foul Brood.

The Nominating Committee presented the names of George J. Abrams and W. A. Price respectively for the offices of Chairman and Secretary.

W. A. PRICE, *Secretary*

REPORT OF THE COMMITTEE ON THE RELATION OF ENTOMOLOGY TO CONSERVATION

The Committee on the Relation of Entomology to Conservation presents herein their annual report on the effects of current entomological practices and probable trends upon the field of conservation. We hope that it may encourage clear vision among entomologists and may help to prevent unwise use of control practices.

All must admit that no insect can be controlled artificially without disturbing the environment, and we have no sympathy with the viewpoint that natural conditions are inviolate. If control operations contribute to man's long time best interest, they are desirable conservation practices. If, however, an activity is unfavorable to man's long time welfare, even though it may produce an immediate benefit, it is in opposition to your committee's concept of conservation. Wise use without waste, and wise management of replaceable resources so that continuous production is assured, is the heart of conservation. The economic entomologist, then, is certainly a conservationist because his objective is to prevent the loss through insect ravages of products valuable to man.

If insect control were a simple matter, involving only the products damaged and the insects causing damage, there would be no need for this committee. But, with the possible exception of household insects and insects that attack harvested or stored products, control practices inevitably affect directly or indirectly many other forms of life.

Usually these incidental influences are inconsequential, but sometimes, and especially when insecticides are involved, they may have far-reaching effects. When potent insecticides are applied to areas of moderate size, like fields, orchards, woodlots, or a few hundred acres of wild lands, any destructive results are transient. Invasion from surrounding lands will usually repopulate such areas promptly, even though they may be completely decimated. If, however, the lands involved are too extensive to permit prompt repopulation, treatment with insecticides, especially the highly toxic new insecticides like DDT, might lead to undesirable effects. No one can say at present where the safe limits lie, but when one considers insecticidal treatment involving thousands of acres or even hundreds of square miles, certainly the treatment in the opinion of your committee approaches hazardous proportions.

To illustrate this point one must resort to a partly hypothetical case. Take for instance a widespread outbreak of the spruce budworm that may easily cover at one time hundreds of square miles. Suppose an insecticide is used against the larvae of this insect. In order to be practical the treatment must kill almost all of the budworms. Incidentally, many other insects will be destroyed leaving a scarcity of insect food for nestling birds. Unless the parent birds can fly beyond the treated area to obtain food, the dependent nestlings will certainly starve. Such treatment, would, then, materially reduce the bird population that, according to various observers, constitutes an important check on budworm multiplication. If at the same time insect parasites and predatory insects are materially reduced in number, the budworms that survive will be free to increase at an accelerated rate. Under ideal conditions a 200-fold rate of increase for this insect is possible, and an actual increase of 100-fold has been observed in the field. Let us assume that the insecticide destroyed 98 per cent of the budworms, and at the same time reduced the pressure of bird and insect enemies to a point that would permit an increase of 100-fold. Despite the 98 per cent mortality, the remaining 2 per cent would produce enough progeny to double the population existing at the time of spraying.

The stage may thus be set for an outbreak of even greater proportions than that originally checked by the insecticide. Granting that this extreme condition may seldom occur, nevertheless destruction of natural control agencies might make it necessary to spray every few years, a requirement that would be absolutely impracticable financially. Thus, the situation might become far worse than if no spraying had been done.

The application of DDT for mosquito control, especially where repeated treatments are made may have serious effects on life in the marshes and adjacent waters, especially where dosages have been relatively high. We are, therefore, not justified in assuming that the treatments made during the war have done inconsequential damage, as some argue. Careful studies that will permit balancing benefits derived from control of mosquitoes against damage to fish and wildlife must be made. Perhaps studies on some of the repeatedly sprayed swamps in the Pacific area might yield some very worth-while results.

Your committee commends the efforts that have been made to determine the effects of DDT on forms of life other than the insects that it is designed to control, and urges the continuation and expansion of such investigations, so that this potent insecticide may be used with minimum risk, and so we shall not be tempted to use it in unwise ways. *Also your committee urges immediate experiments to test in the same manner the effects of various other synthetic organic chemicals that promise to become important insecticides, and we urge that they be used cautiously until their action on other forms of life and on the soil has been determined.*

Other commendable activities that bear upon the use of insecticides in harmony with conservation are now receiving attention. The refinement of spraying devices on airplanes to obtain more uniform coverage with low dosages, the improvement of spray formulation, the application of the thermal-aerosol fog to distribution of insecticides, and the

further development of mist blowers should continue to receive attention, until their possibilities and limitations have been determined. These or other techniques may make the effective control by low dosage more practicable than at present. More important still, careful timing of treatments may increase the possibilities of safe, widespread application of insecticides.

The discovery of new insecticides and the development of new devices for their application have been a by-product of the war. They have directed thinking of the entomological profession toward insecticides. Many years ago, Alvah Peterson asked the question, "Are entomologists too insecticide minded?" Perhaps this question is more to the point today than when it was propounded. With this thought in mind, your committee wishes to commend the work now under way in the United States and Canada on control of the spruce budworm by silvicultural methods. Also we commend the sanitation-salvage cuttings in ponderosa pine designed to reduce bark beetle losses. These operations are contributing much to conservation of forest resources. Similar opportunities, too numerous to mention in this report, exist everywhere, and emphasize the desirability of more general application of ecological technics to the regulation of environmental conditions so that serious outbreaks of insects are not likely to occur.

Ecological investigations concerning the influence of soil conservation programs on insect populations are being sadly neglected. Do the technics used in soil conservation increase or decrease the frequency and severity of insect outbreaks? If some soil conservation technics have bad entomological effects, how can they be modified to produce the desired results from both the entomological and soils viewpoints? Who but the entomologist should direct public attention to this matter?

Your committee wishes to commend the investigations that have been conducted by the Bureau of Entomology and Plant Quarantine in cooperation with the Fish and Wildlife Service on the effects of DDT on wildlife, and similar cooperation between the U. S. Public Health Service and the Fish and Wildlife Service. But such cooperative efforts should not be limited to federal agencies nor to DDT.

Not only should we be studying the effects of insecticidal control on wildlife, but we also should be investigating the effects of insect ectoparasites on wild animals, the role of insects as vectors of mammalian and avian diseases, and the numerous other inter-relationships that exist between insects and wildlife. Also the effects of wildlife management practices on insect populations deserve serious attention and should be attacked by means of ecological technics.

In conclusion, your committee finds that many economic entomologists are becoming more and more conscious of the conservation aspects of entomology. They are beginning to realize the control practices which affect the environment unfavorably cannot be applied indiscriminately. They are seriously taking into consideration the influence of their activities upon the interests of other fields and are beginning to cooperate with other agencies to work out suitable practices.

Furthermore, there is a strong trend in some quarters to apply ecological principles to the control of environment with the object of developing conditions unfavorable for insect outbreaks. Nevertheless, it must be admitted that many entomologists are inclined to adopt a narrow and short time view of insecticidal control and do not give due consideration to the overall and long-time effects of insecticides. We call attention to the dangers of this restricted viewpoint, and urge expansion of ecological studies by the various federal, state and private agencies, in the interest of both insect control and conservation.

R. D. GLASGOW
J. A. BEAL H. B. MILLS
S. A. GRAHAM, *Chairman*

AMERICAN COMMITTEES ON ENTOMOLOGICAL NOMENCLATURE

The activities of the American Committee on Entomological Nomenclature since the annual meeting in March 1946 had three distinct phases. These included the study of certain problems submitted by individuals for Committee consideration, the undertaking of certain broad studies of nomenclatural problems, and a revision of the By-Laws under which the Committee operates.

Among the subjects submitted to the Committee by various individuals and now under Committee investigation with a view to advisory action and possible representations to the International Commission on Zoological Nomenclature are: (1) Misidentified genotypes, (2) The status of names placed on "The Official List of Generic Names in Zoology," (3) The valid name of the Dipterous family Ortalidae *auctt.*, and (4) the status of generic names published after December 31, 1930 without definite unambiguous designation of the type species and certain problems related thereto.

The broader nomenclatural studies initiated by the Committee itself include (1) a study of family names of American Insects (2) a survey of proposals pending before the International Commission on Zoological Nomenclature with a view to obtaining an expression of Committee opinion on matters pertinent to entomological nomenclature for transmissal to the Secretary of the International Commission, and (3) the preparation of a proposal or series of proposals to the International Commission on Zoological Nomenclature regarding the nomenclature of categories of less than subspecific rank.

The Committee also revised and amended its By-Laws. The revised By-Laws follow:

NAME

1 The name of this Committee shall be the American Committee on Entomological Nomenclature.

SPONSORSHIP

2 The Committee exists under the joint sponsorship of the Entomological Society of America and the American Association of Economic Entomologists, to each of which it shall be equally responsible.

OBJECTIVES

3 The objectives of this Committee shall be:
- a To initiate or to further action tending to stabilize the nomenclature of American insects.
- b To make recommendations directly to the International Commission on Zoological Nomenclature or through the International Commission on Entomological Nomenclature on cases involving action of interest to entomologists.

c To give advice on problems of nomenclature that may be submitted to the Committee by any American entomologist.

LIMITATION

4 The Committee in all its actions shall be bound by the International Code of Zoological Nomenclature and by the Opinions of the International Commission on Zoological Nomenclature.

MEMBERS

5a The Committee shall consist of nine members.

5b Three members shall retire each year but shall be eligible for reelection. The term of office of a retiring member shall end at the close of the Annual Meeting.

5c At least two names shall be placed in nomination for each vacancy by the Chairman.

5d Members shall be elected annually by a majority vote of the Committee, but shall be subject to confirmation by the executive committee of each sponsoring organization. The election shall be by mail ballot and shall be completed not less than one month prior to the Annual Meeting.

5e Ballots for members shall be sent to and tallied by a member of one of the sponsoring organizations to be designated by the chairman.

OFFICERS

6a The officers of the Committee shall be a chairman and a secretary.

6b It shall be the duty of the chairman to preside at meetings and to initiate any action, including the appointment of subcommittees, looking towards the fulfillment of the objects of the Committee.

6c It shall be the duty of the secretary to carry on official correspondence, mail ballots, arrange for the preparation of reports and summaries of committee action, render an Annual Report to the Committee for transmission to the two sponsoring organizations, and transact other business.

6d The officers shall be elected annually by a majority vote of the Committee, the election to be by mail ballot and completed not less than one month prior to the Annual Meeting. Election of a retiring member to office shall be tantamount to reelection to membership on the Committee. Newly elected officers shall take office at the close of the Annual Meeting.

6e Ballots for officers shall be sent to and tallied by a member of one of the sponsoring organizations to be designated by the chairman.

TRANSACTION OF BUSINESS

7a The Committee shall be empowered to make such rules as may appear desirable for the handling of its business.

7b Action on matters of nomenclature shall be taken by mail ballot, except that final action on written summaries of matters previously submitted for consideration may be taken at the Annual Meeting.

7c Decisions on matters of nomenclature shall require a majority vote of the Committee, but when the vote is divided five to four the secretary shall submit the case for reconsideration by the Committee. If after reconsideration the vote remains the same, the case shall be submitted to the International Commission on Zoological Nomenclature.

7d Termination of vote on matters submitted to the Committee by mail shall be upon receipt of five votes that agree, except that the vote shall not be terminated in less than 30 days from time of mailing of ballots unless all votes are in.

PUBLICATION

8 Decisions of the Committee shall be published in summary form, or with such additional explanatory remarks as may be deemed appropriate, in the Annals of the Entomological Society of America under the name of Advisory Recommendations.

QUORUM

9 A quorum at any meeting shall consist of a majority of the members of the Committee.

AMENDMENT

10 These By-Laws may be amended by a majority vote of the Committee taken by mail ballot.

Respectfully submitted,
E. G. LINSLEY, *Secretary*

REPORT OF THE COMMITTEE ON COMMON NAMES

Ballots containing proposals for 146 new common names and for changes in 5 previously approved names were distributed to the membership of the Association in March 1946, and 494 ballots were returned. The 131 new names and 3 changes receiving the 80 per cent favorable vote requisite for approval were incorporated in the list of previously approved names; all scientific names were checked by specialists and necessary corrections made; and after some editing of the common names in accordance with instructions to the Committee, voted at the Dallas meeting, a new complete list was prepared for publication. This was published in the August number of the JOURNAL

At the Dallas meeting the Committee was also instructed to develop a list of common names for families and other groups of insects. Little was done on this during the year owing to the time required for the preparation of the new complete list of specific common names. However, about 250 tentative proposals have been placed on cards and filed for later consideration. It is evident, from what has been done thus far, that group common names will require much study before submission of the list to the Association membership for voting. Such a list can probably not be made ready before the spring of 1948.

CLAUDE WAKELAND — H. M. HARRIS
E. H. STRICKLAND — F. W. POOS
DON C. MOTE — C. F. W. MUESEBECK
Chairman

REPORT ON THE COUNCILLORS FOR THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

Your councillors both attended the St. Louis meeting of the American Association for the Advancement of Science held in March 1946, and participated in the sessions of the Council and of Section F.

The officers and members of Section F were clearly favorable to the desire of entomologists to

participate more fully in the activities of the Section and of the Association. Largely as a result of the efforts and interest of the councilors of the two national entomological organizations, Section F, on motion, changed the structure of its Executive Committee to provide for better representation of the constituent organizations.

Science, in the issue of April 26, 1946, described the change as follows:

> "At the business meeting of Section F it was resolved that after 1 January 1948 the Executive Committee of the Section Committee should consist of the elected secretaries of the following affiliated societies: Entomological Society of America, American Society of Zoologists, American Association of Economic Entomologists, American Society of Naturalists, Ecological Society of America, Genetics Society of America, American Microscopical Society, Limnological Society of America, and American Society of Parasitology.
>
> "The Chairman and Secretary of Section F continue as ex officio members of the Executive Committee. It was further resolved that the members elected to the Committee should take office 1 January 1947 and should serve one year only and that the other members whose terms extend beyond 1 January 1948 should continue to serve their term."

The chairman of Section F for 1946, who will preside at the Boston meeting the latter part of this month, is Dr. Alfred E. Emerson of Chicago, an entomologist and ecologist interested in termites. The changes in the organization of the executive committee, of which the Secretary of this Association will be an ex officio member, will become effective on January 1, 1948.

Ballots for election of chairman and committeemen for 1947 were distributed on November 4, 1946. The nominees (chosen by the executive committee) again consisted almost wholly of members of the American Society of Zoologists, some of them being geneticists but none economic entomologists. It is believed, however, that the new provisions for 1948 will officially broaden the field of interest of Section F.

Outside of the business activities of the Section, the subject of greatest interest at the St. Louis meeting was the proposal for organizing an "Institute of American Biologists" with a full time office and Secretary. The proposal follows the general outlines of a suggestion made by Dr. Roger C. Smith of this Association some three years ago and held in abeyance in the meantime.

The proposal is under study by two groups, one informal under the leadership of Dr. D. W. Bronk of the University of Pennsylvania, and the other, a special committee of the National Research Council under the chairmanship of Dr. E. E. Butler of Princeton University. The latter committee met on November 21, 1946, and decided to ask the Division of Biology and Agriculture of the National Research Council to proceed with the establishment of such an Institute. However, the Council has not yet agreed to taking this responsibility, and the whole question is still very much an open issue. In particular, several groups of biologists, such as the agronomists and, I believe, our own Association as well, are independently exploring the possibility of setting up full time offices—which might decrease the support of an Institute intended to cover all biologists.

Your councilors have no recommendation to make on this problem until the situation clarifies somewhat. However, we do not feel that there is any reason as yet for our Association to discontinue any discussions that may be contemplated as to a possible future full time business office of our own.

S. B. FRACKER F. L. CAMPBELL

COMMITTEE REPORT ON POPULAR ENTOMOLOGICAL EDUCATION, 1946

Following the presentation of the report of this Committee at the last annual meeting, there was considerable discussion of the need and functions of this Committee. The matter was referred to the executive committee of the association whose report appears in the JOURNAL OF ECONOMIC ENTOMOLOGY, February 1946, page 104.

In conformity with the recommendations of the Executive Committee, the Committee on Popular Entomological Education was continued and its work expanded. A new method of selecting its membership was adopted. The Chairman of said committee was elected by the Association and the President of the Association was instructed to appoint one member to represent each of the four branches who will serve until members are elected at the next annual meeting of each of the branches.

A number of months elapsed before the President of the Association had acceptance from all members of the committee; however, the committee has had time to give some consideration to its new assignment and has come to the following conclusion:

Though more than 590 statements on entomological subjects have been released by the Bureau of Entomology and Plant Quarantine and the various State agencies during a previous 12 months' period and though an earlier survey showed that more than 600 popular entomological articles were carried by some 300 national, regional or trade magazines, the fact remains that those articles were mostly of the prescription type or related to uses of new insecticides and that except for a few chance articles based on interviews by some magazines, little has been written to cause the public to recognize entomology as a profession.

Your Committee feels that if the entomologists expect to reach the public and sell them the idea that entomology is a profession they need to write more for the public than merely for the benefit of other entomologists. To sell the public on the fundamentals of entomology, authors should cover the scope of the entomological associations and their work; insects and the whole biological complex; the way in which knowledge of life histories of insects aids in contol, how man has harnessed insects and made them work for him, etc. This might be done by actually writing articles on these subjects or by preparing digests of sufficient content to stimulate professional writers to use such digests in the writing of articles. It has been suggested that more popular articles or digests might be forthcoming if writing contests were set up where prizes or awards would be given or possibly by having some leading entomologist in each State responsible for getting or writing at least one article each year.

Some of the articles or abstracts of articles might be directed to the scientists in other fields. Also *Biological Abstracts*, etc. might be supplemented with technical reviews calling attention to significant entomological papers of recent publication. Such reviews might call attention to the work and results.

At the suggestion of your Committee, the Bureau of Entomology and Plant Quarantine plans to pre-

pare a publication to meet Bureau needs on entomology as a profession.

Another method of reaching the public might be a pictorial presentation of what the Profession of Entomology Means to Mankind. Your Committee has found that the Associated Serum Products, Inc. has been preparing, over the past several years, a number of drawing to portray "What the Veterinary Profession Means to Mankind." These are about $5\frac{1}{2} \times 9\frac{1}{2}$ inches in size with just enough text to explain what the pictures are about. Mats of these are provided various magazines. It would appear that similar pictures could be drawn or photographed to show the public what have been the contributions to mankind by the entomological profession. Some of the subjects to be covered might be:

1. Typhus outbreak stopped through louse control.
2. Tropical diseases reduced by controlling insect vectors with DDT.
3. Practically eliminated typhoid and dysentery through house fly control.
4. Valuable land made habitable by mosquito control.
5. Development of rotenone a safe insecticide for use on edible vegetables.
6. More sanitary flour mill products provided by flour mill fumigation.
7. Cotton industry made more secure through boll weevil control.
8. Protected wheat industry by working out safe planting dates to avoid Hessian fly damage.
9. Production of Smyrna type figs in this country made possible by introduction of a pollinating insect.
10. Quarantines protect American agriculture.
11. Classification of 700,000 kinds of insects, 85,000 in this country.
12. Entomologists guiding public in use of insecticides worth $100,000,000.00 annually.

The above twelve items would provide one each month for a year and sufficient additional items of note are available to run for many years if the Association alone, or with outside help, could get the machinery in motion to promote and finance this project.

It may be of interest to report that the Policy and Program Committee of the American Society of Agronomy recently recommended that their Society publish a semi-popular magazine to serve the large number of people between the scientist and the farmer as well as farmers and farm managers having more than popular interest in the new development. The Agronomy Committee estimates a circulation of 5,000 copies. With a subscription rate of $3.00 per year and the advertising revenue the magazine would be self supporting.

The interest of the press is expressed in a letter your committee received from an associate editor of a national magazine in which he asked that his name be placed on the mailing list to receive all releases issued by your Committee. The letter stated also that:

"We are anxious to publish only authentic research data, but can't ignore subjects for the months often needed to get a paper published in a science journal. Your committee can do a valuable service of great mutual benefit. The recent fiasco on news about DDT is the perfect 'horror' example of what must happen when the entomologists refuse to release official views on a material already a commercial product available to consumers."

The above letter expresses very effectively the attitude of the press. They want authentic information but are not content to wait until such can be provided. They fail to realize that most entomologists do not wish to release information until absolutely certain that similar results will be obtained by other workers and by the general public, and furthermore that Federal entomologists and many commercial entomologists are not in a position to release such information as they have gathered until the material is approved for publication or is published. The editor attitude as expressed emphasizes the need for entomologists to visit with the editors of farm and popular magazines and help them to understand the policies for approval of research information and solicit their cooperation in releasing only authentic information, also to make sure the sensational type of information they use is scientifically correct and that it will not be misinterpreted by the readers. We should also help them see the value to the public of presenting factual basic information though it may not be given to the press immediately after discovery.

Your Committee will transmit to the magazines material which is submitted to it, but as a result of experience during the past year no member of the Committee had time to canvass the field in an attempt to locate material which would be of popular interest, nor did they have time to prepare such articles themselves.

Though your Committee did not develop a definite plan for supplying editors of popular, trade, and the commercial press with basic scientific data from which popular articles might be developed, it has presented the above suggested procedures with the hope of getting an expression of opinion from the membership of the Association on the merits of the various suggestions. In this connection your Committee recommends:

1. That the Association set its plans towards giving its editor a full time assistant or towards the employment of a full time editor who would also prepare popular entomological information.
2. That the Association raise a developmental fund in an amount necessary to permit the editor or his staff to assume his added responsibilities.
3. That the Association support a writing contest to stimulate the preparation of popular entomological articles and to award prizes ranging $25.00 to $100.00 for the 10 best articles. The total fund not to exceed $500.00.
4. That the Association set aside an annual fund of $500.00 to sponsor the entomological writing contest.
5. That the Association support a plan to provide mats for use in popular magazines depicting what the Profession of Entomology Means to Mankind, and that a survey be made to determine the cost of such mats and of possible financial sponsorship.
6. That the Committee be authorized to make contact with some monthly magazine, such as: *Popular Science Monthly, Scientific Monthly, Popular Mechanics, Nature,* or similar publications to ascertain the possibility of their agreeing to supply a certain number of pages

each month for well illustrated popular writings in the entomological field, providing a plan can be worked out for securing acceptable articles.

7. That The Entomological Society of America and The Agricultural Insecticide and Fungicide Association, The National Association of Insecticide and Disinfectant Manufacturers, and The Pacific Insecticide Institute be invited to participate in the program to popularize the Profession of Entomology.

R. C. SMITH K. P. EWING
L. G. SMITH J. O. PEPPER
M. P. JONES, *Chairman*

REPORT OF THE COMMITTEE ON THE CODLING MOTH

As in many previous years, the Committee on the Codling Moth has performed two chief functions. The first of these has been to arrange for the compilation and distribution of a pool of information on the results of codling moth investigations during the preceding year. The Bureau of Entomology and Plant Quarantine is again undertaking this service, and contributions are now being invited from various workers who carried on investigations with the codling moth during 1946.

It was now been nine years since a general conference has been held. With the introduction of DDT and the numerous problems that have arisen from its use, the Committee has decided that the time is now ripe for another general conference. An effort was made to arrange for such a conference in conjunction with the national meetings, but because of the crowded condition of the program there did not seem to be a satisfactory time for it. The Committee has therefore voted to hold the general conference in conjunction with the meetings of the North Central States Entomologists Branch, which are to be held at Des Moines, Iowa, March 26–28, 1947. The conference will probably be held on March 25. Detailed arrangements are now being made and will be announced later.

L. F. STEINER W. J. O'NEILL
B. F. DRIGGERS A. D. BORDEN
DWIGHT ISELY B. A. PORTER, *Chairman*

REPORT OF THE PUBLICATIONS COMMITTEE

Your committee has given careful consideration of publication problems which have come to its attention and makes the following recommendations and suggestions:

1. Manuscripts should be considered as proper material for publication in the JOURNAL if they deal with arthropods which affect crops or man's belongings and which are commonly recognized as problems to be referred to the entomologist; otherwise publication may be accepted at the discretion of the Editor.

2. That the temporary policy of accepting papers of unlimited length, approved a few years ago, be continued until conditions necessitate change. However, the Editor should be given discretion in the acceptance of papers of unusual length.

3. Short notes and similar items and observations, especially if of a preliminary nature, are much desired and therefore members of the Association are urged to submit such items to the Editor.

4. That the JOURNAL maintain a conservative policy on the use of new insecticide names and discourage multiplicity of names for the same chemical. No names consisting of numerals alone should be used because of indexing difficulties.

In this connection it is our recommendation that the Committee on Insecticide Nomenclature take the initiative in standardizing common names for new insecticides or in providing new names to the end that only one common name for a new chemical may get into the JOURNAL index.

5. We commend the Editor of the JOURNAL for his excellent work and faithful service under the most trying conditions.

We nominate L. M. Peairs to continue as Editor of the JOURNAL

Since only three committee members were present, we called in J. S. Houser who gave us of his knowledge and experience in preparing this report.

Respectfully submitted,
B. A. PORTER T. L. BISSELL
J. J. DAVIS, *Chairman*

REPORT OF THE COMMITTEE ON COOPERATION WITH PEST CONTROL OPERATORS FOR 1946

There is a recognized need for cooperation between commercial pest control operators and technical entomologists with regard to the appreciation of mutual problems. It was on this basis that the committee was formed approximately 10 years ago. Since that time these two groups have been cooperating along the following lines:

LEGISLATION.—The first real work of the committee had to do with the formulation of a model law for pest control operation. While a model law still hasn't been perfected, one approaching this ideal is under consideration in Florida at the present time.

LITERATURE.—It is generally recognized that there is inadequate information with regard to the formulation of insecticides and their application, in the field of commercial pest control. This committee has been active in improving the methods of presenting literature in this field.

EDUCATION.—Education has been a very important function of this committee, and as a result of its efforts Regional Pest Control Conferences for pest control operators, have been established in the following institutions: Purdue University, 1936; West Coast Conference, The University of California, 1937; Southern Conference at Louisiana State University, 1938; Eastern Conference at Massachusetts State College, 1940; Canadian Conference at University of Montreal, 1943.

In addition to these Regional Conferences there have been many such state meetings for pest control operators, at educational institutions namely, at Rutgers University at New Brunswick, New Jersey; Michigan State College, East Lansing, Michigan; University of Florida, Gainesville, Florida; University of Wisconsin, Madison, Wisconsin; Fordham University, New York, New York; Cornell University, Ithaca, New York; University of Toronto, Toronto, Canada; and there will be a new one in 1947 at Pennsylvania State College, State College, Pennsylvania.

There have also been many state and local meetings, where entomologists and institutions have cooperated in providing their services if requested.

It is particularly notable that pest control operators are not making hit and miss insect identifications, but are depending more and more upon the services of federal and state experiment station

entomologists for correct identifications and aid. There has been a very definite cooperation of the National Pest Control Association by way of publicity, financial and otherwise, in the promoting of additional programs. The National Pest Control Association has also offered its facilities in providing lists of respective state members to state officials, including county agricultural extension agents. These lists can be secured from the National Pest Control Association upon request.

Another interesting development in the educational field has been the establishment of a four year curriculum for pest control operation studies, at Purdue University.

RESEARCH.—There is more and more need of cooperation between research men and pest control operators in developing and supporting a sane approach to adequate control recommendations. An example was the cooperative program between pest control operators and official entomologists that occurred during the war when an all-out attempt was made to determine the efficiency of DDT for the control of household and institutional types of insect pests. This type of approach to the study of a new insecticide should be seriously considered in the future. The present committee is in position to aid in such a cooperative test program.

H. A. U. MONRO F. W. FLETCHER
E. G. LINSLEY, *Chairman*

REPORT OF THE RESOLUTIONS COMMITTEE

The Committee on Resolutions presents the following report:

1. WHEREAS, the members of the American Association of Economic Entomologists, in attendance at the fifty-eighth annual meeting of this Association held in Richmond, Virginia on December 9–12, 1946, have enjoyed a most pleasant and profitable assemblage,

   THEREFORE BE IT RESOLVED: That we hereby express our cordial appreciation to the following individuals, groups, and agencies who made this occasion possible:

   a. Chairman P. D. Sanders, G. T. French, W. E. Bickley, R. B. Arnold, R. W. Brubaker and J. P. Vinzant, members of the local Committee on arrangements, for their efforts in our behalf.
   b. Program Committee for excellent, informative and stimulating program.
   c. The Administrative and operational personnel of the Hotel John Marshall for their many courtesies.
   d. Our President and Secretary for so ably fulfilling their duties during the meeting and in making preparations therefor.
   e. The officers and members of the Entomological Society of America for their splendid cooperation in making this joint meeting a success.
   f. The committee on local arrangements at Pittsburgh, consisting of A. C. Miller, Chairman, Arnold Mallis, H. G. Guy and W. R. Sweadner, and the management of the William Penn Hotel, for their cooperation in making plans and preparations for the meeting and their courtesies and cooperation in expediting the transfer of reservations and other necessary business in transferring the meeting to Richmond.
   g. Dr. J. Van der Vecht for his fascinating and informative address on his entomological experiences under war conditions.
   h. The numerous companies which provided the funds for the entertainment and other special features of the banquet.
   i. The cooperation of the local and associated press for their splendid coverage of the meeting.

2. WHEREAS: The insect surveys conducted during the war emergency proved of great value in the detection of destructive pests, both established and possible new importations, and provided a necessary basis for the initiation of steps to prevent extensive losses.

   THEREFORE, BE IT RESOLVED: That this association urge the provision of funds for the expansion and intensification of present surveys as the first step in the activation of work in preventive entomology—such surveys to be conducted cooperatively by the U. S. Bureau of Entomology and Plant Quarantine and various state agencies.

3. WHEREAS: The losses to our forest resources caused by insects exceeds that caused by fire, and the destruction caused by insects destroys the natural beauty of our forests, increases fire hazards and removes protection need for watershed, and

   WHEREAS: The insect pests destructive to forests occur on lands irrespective of ownership, and their effective, economical or feasible control depends on early detection of pending outbreaks and prompt application of control measures, and

   WHEREAS: Any program for the protection of our forest resources from insect pests requires cooperative, coordinated action of landowners,

   THEREFORE, BE IT RESOLVED: That the American Association of Economic Entomologists urge that there be developed in the various states and by the Federal government an adequate program for the detection of infestations of forest insect pests in their incipient stages, and procedures for carrying out cooperative control practices on forest lands, and

   BE IT FURTHER RESOLVED: That we urge the consideration by State and Federal governments of legislation which will provide for a program of this nature.

4. WHEREAS, The war years have witnessed the fruition of many years of research in the production of potentially valuable but also potentially dangerous chemical compounds, and

   WHEREAS: The intelligent, beneficial, safe and productive use of such chemicals for the protection of man, his animals and his crops involves adequate and extensive research by qualified scientists, and

   WHEREAS: A complete understanding and appreciation of problems involved is needed by those responsible for the appropriation of public funds,

   THEREFORE BE IT RESOLVED: That legislative groups and committees of the Nation and the various states thereof be informed that it is the opinion of the American Association of Economic Entomologists that an expansion of funds, personnel and equipment of the various qualified research agencies is essential for the protection of the public and the full utilization of the values of new potent tools for the suppression and eradication of insect and related pests.

   AND BE IT FURTHER RESOLVED: That the Secretary of this Association be instructed to send a copy of this resolution in the form of a letter to the chairmen of the Committees on Appropria-

tions and on Agriculture in the Congress and each of the State legislatures.

5. WHEREAS: There is a lack of uniformity in the requirements of State Economic Poison Laws and the regulations thereunder, and

WHEREAS: such lack of uniformity obstructs the efficient distribution of economic poisons and works unnecessary hardships on the ultimate users of insecticides and fungicides,

THEREFORE BE IT RESOLVED: That in order to alleviate the present undesirable situation, the American Association of Economic Entomologists urges the appropriate individuals and agencies within the states to give serious consideration to the Model State Insecticide and Fungicide Act as drafted by the Council of State Governments.

WHEREAS, it is generally recognized that the existing Federal Insecticide Laws and regulations are inadequate to meet present day conditions,

WHEREAS: suitable laws and regulations are necessary for the proper control of economic poisons that move in interstate commerce, and that are essential to agriculture and the public,

THEREFORE, BE IT RESOLVED: That the American Association of Economic Entomologists recommend an immediate and thorough revision of the Federal Insecticide Laws.

WHEREAS, two honored and beloved charter members of our Association, Dr. L. O. Howard and Dr. Herbert Osborn, were unable to attend this meeting except in spirit,

THEREFORE, BE IT RESOLVED: That our Secretary be instructed to forward to them our sincere greetings and best wishes.

WHEREAS, thirteen of our worthy members, A. Robert Thompson, Stanley H. Logan, K. B. McKinney, Leland Wolfe, Norwood A. Eaton, T. J. Headlee, John Alsterlund, Harry H. Whall, B. H. Walden, Grace H. Griswold, T. H. Frison, U. C. Loftin, J. H. Merrill and R. H. Pettit, were called to their eternal reward during the past year,

THEREFORE BE IT RESOLVED: That we put in our permanent records this expression of our regret at the death of these our friends and fellow workers.

G. F. McLEOD B. A. PORTER
G. C. DECKER

REPORT OF THE NOMINATING COMMITTEE

To the President and Members of the American Association of Economic Entomologists:

The Nominating Committee makes the following recommendations for officers, members of Committees, representatives and councilors for the year 1947:

President: Ernest N. Cory
First Vice President: B. A. Porter
Vice Presidents (Chairmen of Branches and Sections):

J. O. Pepper	Eastern Branch
Charles E. Smith	Cotton States Branch
M. A. Stewart	Pacific Slope Branch
J. S. Houser	North Central States Branch
Roy Richmond	Section of Plant Pest Control and Quarantine
———	Section of Apiculture
W. C. Nettles	Section of Extension
Alvah Peterson	Section of Teaching
S. A. Rohwer	Section of Insecticides

Branch and Section Secretaries;

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John T. Creighton	Cotton States Branch
Roy E. Campbell	Pacific Slope Branch
James W. Apple	North Central States Branch
C. R. Willey	Section of Plant Pest Control and Quarantine
W. A. Price	Section of Apiculture
C. F. Stiles	Section of Extension
W. P. Hayes	Section of Teaching
C. S. Harris	Section of Insecticides

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E. N. CORY, Chairman (*ex officio*)
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G. E. Lehker (1949)
Committee on Common Names of Insects
A. V. Mitchener (1949)
G. J. Haeussler (1949)
Publications Committee
W. E. Dove (1949)
W. H. White (1949)
J. A. Munro (1949)
Program Committee
E. F. Knipling (1949)
Committee on Codling Moth
G. Edw. Marshall (1949)
P. J. Chapman (1949)
Committee on Insecticide Terminology
Glenn Carman (1951)
Committee on Popular Entomological Education
George S. Langford, Chairman
Committee on Cooperation with Pest Control Operators
George Hockenyos (1949)
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Committee on Relation of Entomology to Conservation
N. D. Wygant (1949)
F. C. Craighead, *Chairman*
Committee on Grasshopper Research
Ephriam Hixson (1949)
Sam McCampbell (1949)

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Trustees for Crop Protection Institute
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Representative on Council of Union of Biological Societies
R. C. Smith (1948)
Councilor for the American Association for the Advancement of Science
B. B. Pepper (1948)
Representative to the National Research Council
H. H. Shepard (1949)

J. J. DAVIS P. D. SANDERS
H. F. DIETZ, *Chairman*

REPORT OF THE COMMITTEE ON INSECTICIDE TERMINOLOGY

Last year, the Committee on Insecticide Terminology presented a set of rules under the title, "A Guide to Insecticide Nomenclature" (JOURNAL 39,

109–110, 1946), which were intended to serve as an initial effort toward the unification of insecticide terminology for use in the JOURNAL OF ECONOMIC ENTOMOLOGY. These rules were adopted by the Association; they appear to have met with general favor and, on the whole, they seem to be workable. Your Committee wishes at this time to call the attention of the members of the Association to these rules, and suggest that they be read carefully, and that any recommendations or comments concerning them be made known to the Committee.

The present Report asks your approval of a modification of the rule on trade-marked names which was adopted last year; in addition, it offers some comments on the adoption of substitute names for unwieldy chemical names and for trade-marked names of insecticides, and other chemical substances which are used to control insects and related animals.

TRADE-MARKED NAMES.—In the Report for 1945, the paragraph on trade-marked names (p. 110) reads as follows: "These (names) shall be used (1) only for the purpose of simplification following a full statement of formulation or, (2) where the composition of the mixture is known not to have been recently changed and the manufacturer has stated in good faith that the composition will not be changed in the future. Wherever practicable, trade-marked names should be relegated to a footnote and a simple but adequate chemical name be used in the text and tables." The change for which your approval is asked follows: Trade-marked Names. Wherever possible, the copyrighted trade-marked names of insecticides and of other chemical substances used to control insects which are mentioned in articles submitted for publication in the JOURNAL shall be placed in footnotes and suitable equivalents of these trade-marked names shall be used in the text and tables of the articles.

Adoption of this modification of the rule on trade-marked names will bring no hardship to the insecticide industry. Inquiry made during the past year among several representatives of insecticide manufacturers by one member of the Committee failed to find any opposition to this proposal. One state experiment station has followed this procedure in its publications for a number of years with satisfaction and freedom from criticism. The phrase, "wherever possible," gives the editorial staff sufficient latitude to handle difficult cases. It is believed the adoption of this modified rule will give a more dignified appearance and a better scientific tone to the JOURNAL.

ADOPTION OF SUBSTITUTE NAMES FOR INSECTICIDES.—The need for suitable names as substitutes for unwieldy chemical names and for trade-marked names of insecticides, implicit in the report of the Committee for 1940 (JOURNAL 34, 140, 1941), is again emphasized in the constructive editorial comments published in the JOURNAL for June 1946 (39, pp. 421–2) under the heading "What's in a Name." For several years this Committee has given consideration to the adoption of such names for use in the JOURNAL and other publications of the Association. It was apparent, however, that the naming of insecticides would be of concern to everyone who makes, sells, uses or investigates these products, and that entomologists, alone, should not take the responsibility of bestowing the names. The name of an insecticide should meet with general approval if it is to enjoy wide and continued usage. The following suggestions are offered on this subject for consideration and action of the Association:

1. The Committee on Insecticide Terminology shall be empowered to cooperate with the American Chemical Society, and with other interested agencies such as associations representing insecticide manufacturers and regulatory agencies engaged in enforcing Federal and State laws in proposing suitable names for unwieldy chemical names and trade-marked names of insecticides, attractants, repellents, and other chemical substances used for controlling insects and related animals.

2. After the names are approved by the Committee on Insecticide Terminology, and by other interested agencies, they shall be submitted to the members of the American Association of Economic Entomologists for approval or rejection. It is suggested that approval be determined by ballot vote of the members. (Note amendment from the floor.)[1]

3. Only chemical substances which have been evaluated in the laboratory and have been shown ready for field trial as control agents shall be considered for naming.

4. The names chosen shall be reasonably short and easily pronounced; designations such as DDT and DD mixture should be discouraged if they are confusing; and numerals such as 666 and 1068 because they are difficult to index.

Your Committee feels that the Association should proceed deliberately with the naming of chemical control substances. Many new insecticides will become appropriately named without action of the Association during their period of experimental use; if the Association favors the use of names that are not copyrighted in its official publications, that position in itself may hasten the establishment of suitable names for many insecticides.

J. R. EYER H. H. SHEPARD
R. C. ROARK C. H. RICHARDSON, *Chairman*

REPORT OF THE MEMBERSHIP COMMITTEE

The Membership Committee reports that it has considered the applications for membership submitted by 167 persons. These were properly certified and in due form and accompanied by the required fees. They are accordingly recommended to the Associa for election to membership.

The Committee further reports that the Association has lost from its membership roll during the past year 48 members. Of these 14 resigned, 14 have died and 20 were dropped for non-payment of dues.

The following members have changed their status: Philip Marvin has become a life member; R. A. Cooley, V. E. Shelford and D. L. Van Dine have been made Honorary Retired members.

H. L. SWEETMAN, *Chairman*

The names recommended were accepted by the Association and a list follows.

[1] It was moved and seconded from the floor that this report be amended to conform with a suggestion from Professor Peairs. The motion was carried. This amendment authorizes the Committee to make final decision on suitable names after consultation with the other interested groups, and to inform the editor at once without a membership ballot, thus by prompt action to discourage the misuse of common names. Because time was not available for correspondence between the committee members the report is printed here as originally read and the amendment appended in this fashion.

LIST OF NEW MEMBERS[1]

Abdel-Malek, Albert
Acree, Fred, Jr.
Alden, John C.
Arbuthnot, Kenneth D.
Barthel, W. F.,
Bauman, Harry H.
Benham, John F.
Berg, George H.
Berg, Philip W.
Bergman, George J.
Berry, Robert
Bishop, Charles F.
Bovien, Prosper
Bowery, Thomas G.
Brazeal, Claborne B.
Brescia, Frank
Broadus, Edward P.
Brooks, Ivan C.
Broullette, Marvin J.
Brown, Leland R.
Bucher, Gordon E.
Bucholtz, Alexander F.
Buckley, M. S.
Bugielski, Frank V.
Butler, George D., Jr.
Calderon, Jose Guevara
Callan, Edward McC.
Camson, Edwin J.
Carbonell, Carlos S.
Carpenter, Guy E.
Chao, Jowett
Clark, James A.
Clark, William K.
Coffman, George W.
Connell, Walter A.
Conner, James T., Jr.
Connin, Richard V.
Cravens, Marcus E.
Crissman, William I.
Crumb, S. E., Jr.
Curtiss, Alfred C., Jr.
Darsie, Richard F., Jr.
Davis, Louis G.
Deer, James A.
Dennis, Norman M.
Dorward, Kelvin
Duncan, Daniel U., Jr.
Dyme, Harry C.
Edwards, Fred I., Jr.
Fisher, John R.
Fischman, Arnold E.
Flock, R. A.
Fluke, Barnaby, C.
Fontaine, Russell E.
Fox, Irving
Garlick, William G.
Garner, Lisle W.
Gerry, Bertram I.
Gesell, Stanley G.
Gilbert, Engel L. R.
Glen, Robert
Glover, Robert S.
Gray, Henry E.
Gresham, William B.
Haas, Carstens Y.
Hall, Stanley A.
Harris, Herbert H.
Harris, Lewis P.
Harris, Vernon C.
Hart, John William
Hazen, Anita C.
Hermann, Adelheid M.
Hoffman, Julius R.
Horen, W. Peter
Iturbe, Alfonso Cortes
Iverson, Leo G. K.
Johnson, T. C.
Kent, Ellis C.
King, Charles A., Jr.
King, Charles E.
Kirsch, Fred A.
LaHue, Delmon William
LaMer, Victor K.
Land, James E.
Larson, A. W.
Laudani, Hamilton
Lawson, Fred A.
Lemmon, Allen B.
Lett, Edmond R., Jr.
Linduska, Joseph P.
Loyola, Jose Terrazos
Little, Donald H.
Luckmann, William H.
Ludvick, George F.
McLeod, William S.
McWilliams, Joseph G.
Maxwell, Lewis S.
Mayeux, Herman Sidney
Merrill, Leland G., Jr.
Miller, William D.
Morris, Ralph L.
Mullett, Robert P.
Murphy, Charles E.
Myers, L. Emery, Jr.
Myser, Willard C.
Niswander, R. Emerson
Olson, Robert E.
Ott, Donald J.
Paullus, James H.
Pederson, Calvin E.
Pence, Roy J.
Perner, Frederick H.
Piesbergen, Norman R.
Pippin, Warren F.
Quisenberry, Benson F.
Rapp, Janet L. D.
Raski, Dewey J.
Redlinger, Leonard M.
Reed, John Preston
Reichart, Charles V.
Reynolds, Harold R.
Rhoades, Winfred C.
Richardson, Ben H.
Rodriguez, Juan G.
Rogoff, William M.
Rouse, Glenn F.
Roussel, John S.
Rudick, Jack
Sacktor, Bertram
Shallow, Donald D.
Sharpless, Ridgway V.
Skow, Al
Slocum, John B.
Smith, Willie Ray
Srivastava, Anand, S.
Steinhauer, Charles J.
Stoker, H. Laurin
Stoner, Warren N.
Sumner, William B.
Swanson, Clark H.
Tarshis, I. Barry
Tashiro, Haruo
Tate, Homer
Thomas, George W.
Thompson, Hugh E.
Thorne, Fred T.
Tibbetts, Ted
Tilemans, Em. M. J.
Titensor, Claine E.
Trawick, Willie Lee
Tuttle, Donald M.
Underhill, R. A.
Utter, L. Gordon
Vannote, Robert L.
Vincent, Lloyd E.
Waites, Robert E.
Walker, Claude A.
Walters, Hubert J.
Washburn, G. Edwin
Walz, Arthur J.
Weaver, Clyde R.
Weems, Howard V., Jr.
West, Fenton T.
Whittemore, Frederick W., Jr.
Wilson, Mark C.,
Woodruff, Nancy
Woolley, Vernon L.
Yancey, Robert M.
Yeomans, Alfred H.
Yolles, Seymour

[1] Mailing addresses will be found in the complete membership list in the "Official Roster."

REPORT OF THE CROP PROTECTION INSTITUTE

The work of the Crop Protection Institute has expanded in 1946 as compared with any previous year. The number of companies now supporting investigations through the Institute is greater than at any time in the past, and the character of the work itself is more diversified. Some of the projects now in hand are extensive and are conceived on a long-time basis. Others are exploratory in nature and are intended to disclose compounds, or groups of compounds, which might be investigated more thoroughly as new insecticides, fungicides, herbicides, or other useful materials.

The Board of Governors of the Institute in 1946 included the following: A. M. Boyce, California (Riverside) Experiment Station, D. M. DeLong, Department of Entomology, Ohio State University, and W. C. O'Kane, New Hampshire Experiment Station, Chairman, representing Entomology; H. W. Thurston, Jr., Pennsylvania Experiment Station, Vice-Chairman, J. G. Horsfall, Department Plant Pathology and Botany, Connecticut Experiment Station, and C. R. Orton, Director, West Virginia Experiment Station, representing plant pathology; S. E. A. McCallan, Boyce Thompson Institute, National Research Council; W. H. MacIntire, Tennessee Experiment Station, and H. J. Patterson, Director Emeritus, Maryland Experiment Station, representing chemistry.

Early in 1946 the Board of Governors made provision for a new administrative officer, who would take over various duties in connection with the management of Institute affairs, and would work with the Chairman of the Board. He would be a full time, permanent employee, and would be situated at the Institute's administrative headquarters, in New Hampshire. Dr. M. D. Farrar of the Illinois Natural History Survey was elected by the Board to this new position, and was given the title Associate Director. Doctor Farrar assumed his new duties and transferred his residence to New Hampshire July 1. He has taken over a substantial part of the detailed direction of Institute projects and is working with the Chairman of the Board in contacts with industries which are maintaining projects with the Institute. Doctor Farrar was once a member of the research staff of the Institute and has long been in touch with its activities. As a scientist of established standing he is well known to entomologists.

The research activities of the Institute in 1946 have included investigations in many categories, some of them new.

Exploration of new organic compounds continues to occupy substantial attention. These compounds originate in several industrial laboratories which possess the staff and equipment, and the background of knowledge, essential for the intelligent synthesizing of new materials. Many hundreds of compounds have been explored in a preliminary way. A considerable number have been given more intensive study.

Chemical groups represented are numerous. They include among others many sulphur compounds, such as mercaptans, polysulfides, and thioethers; a large number of chlorine compounds; a long series of nitrogen compounds, including primary, secondary, and tertiary amines, and related linkages; many alcohols, ethers, esters, and ketones; and various metallo-organic substances—to mention only a part of the groups studied.

In all of this work the chemists who are synthesizing the compounds are kept in close touch with the entomologist, plant pathologist, and plant physiologist who are conducting the biological studies. When a chemical gives interesting performance in one or more of the various exploratory techniques, related compounds are selected or synthesized in order to proceed in the direction of more effective performance. The results, in turn, suggest further lines of advancement. By this process the ultimate development of new and useful materials becomes slowly more orderly and logical.

The fields of useful activity in which compounds are now in process of exploration by the Institute are of considerable number. In the subjects of special interest to the entomologist they include stomach poisons, contact insecticides, repellents for flies and mosquitoes, repellents and toxic compounds for mites attacking human beings, repellents and contact agents for ticks, mothproofing compounds, formulations for aerosols, ant baits, and methods of formulating DDT in sprays and dusts. In a related line of inquiry an investigation is under way in the performance of various inerts as extenders for insecticide and fungicide dusts. In another related investigation tenacity agents for dusts and sprays are under study.

In subjects of special interest to plant pathologists extensive work continues toward the development of better and safer fungicides for applications on plants, treatment of seeds to control seed-borne diseases, and treatment of soil to prevent loss of seedlings from organisms living in the soil. An extensive investigation is under way with new compounds which may serve as safe and effective herbicides for application as sprays. A related investigation is concerned with treatment of soil to prevent germination of weed seeds. Another series of experiments with soil treatments is concerned with control of nematodes.

In the field of livestock treatments investigations are in progress looking toward compounds for the control of internal parasites, such as round worms in sheep and caecal worms in poultry.

Not infrequently an Institute worker finds that he needs a new or improved technique for exploratory tests with new compounds, or for more exact laboratory or greenhouse studies. Recognizing this need the Board of Governors of the Institute have authorized a program designed to provide new apparatus or methods which would be useful both to entomologists and to plant pathologists. The expense of this is being financed by the Institute out of its reserve funds. As useful apparatus is devised or methods are developed, they will be published in appropriate channels.

Companies supporting organized research through the Crop Protection Institute in 1946 included the following:

Animal Trap Company of America
Armour & Company
J. T. Baker Chemical Company
Battelle Memorial Institute
Boliden Mining Company
Carbide and Carbon Chemicals Corporation
Davison Chemical Company
Edco Corporation
Ethyl Corporation
General Chemical Company
Johns-Manville Corporation
Mallinckrodt Chemical Works
The Mathieson Alkali Works, Inc.
Minnesota Mining and Manufacturing Company
New Jersey Zinc Company
S. B. Penick & Company
Pennsylvania Engineering Company
Rohm & Haas Company
The Texas Company
Vick Chemical Company
U. S. Industrial Chemicals, Inc.

Research associates, assistants, and technicians employed by the Institute in 1946 included the following:

Raymond W. Barratt, Asher Capelle, Clare Chaplinski, Donald P. Connola, Edith Converse, Raymond Cowles, David G. Doerfler, Stuart D. Edmond, Mary B. Fetherston, Corinne Flint, Carter Funnell, John B. Harry, Harry Haynes, Carl Henrickson, Lawrence J. King, David Laddey, Basil G. Markos, Arthur Matte, Wallace J. Morse, L. C. Murphree, Winifred Musch, William O'Dair, Irene Skok, Howard W. Smith, Ruth Smithers, Anthony A. Sousa, Mary Steinmetz, Nancy Woodruff.

The Institute has resumed publication of research bulletins, following the war period in which publication was suspended. Two new numbers in the bulletin series have now been printed as follows:

"Diatomaceous Diluents for Dusts," by Neely Turner.

Two papers, combined in one bulletin, including the following:

"Glyoxalidine Derivatives As Foliage Fungicides. I. Laboratory Studies," by R. H. Wellman and S. E. A. McCallan; and "Glyoxalidine Derivatives As Foliage Fungicides. II. Field Studies," by H. W. Thurston, Jr., John B. Harry, F. H. Lewis, A. B. Groves, and C. F. Taylor.

W. C. O'KANE

OFFICIAL ROSTER

AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS
JOURNAL OF ECONOMIC ENTOMOLOGY

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* Chairman in 1945.

** Continued because no qualified successor was elected.

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GLENN CARMEN, Riverside, Calif. (1951)

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Representative to the National Research Council

H. H. STEPARD, Washington D. C. (June 30, 1949)

JOURNAL OF ECONOMIC ENTOMOLOGY

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Aamodt, T. L., University Farm, St. Paul, Minn.
Abdel-Malek, Albert, Box 3081, Univ. Sta., Columbus 10, Ohio
Abell, Earl F., 93 Ellsworth Ave., Toronto, Can.
Abramitis, Walter William, 170 Boston Ave., Hillside, N.J.
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